Scaling Up Rice Fortification in Latin America and the Caribbean

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Editorial

The fortification or enrichment of staple food with essential vitamins and minerals is not a new concept. Since the first trials in the 1920s, it has been an effective public health strategy to prevent micronutrient deficiencies in general populations and today many countries in the world fortify one or more staple foods. The food items most frequently fortified are cereals (wheat and maize flour), milk and milk products, edible oils, sugar, salt, and specialized foods such as fortified blended food. The potential for using rice as a vehicle to increase the intake of essential vitamins and minerals is huge. Rice is the dominant staple food of approximately half of the world's population. In Latin America and the Caribbean (LAC), it supplies on average 27% of daily caloric intake, ranging from 8% in Central America to 47% in the Caribbean (FAOSTAT). The region produces more than 28 million tons of paddy annually – the vast majority in South America – representing more than 5% of the world's output.

Over the past decades, scaling up of rice fortification has been hampered by technological limitations. Today, affordable technology exists to produce fortified rice kernels that look and taste like non-fortified rice. Advances in coating and extrusion technologies allow micronutrients to be retained effectively even after long washing and cooking processes, which makes rice fortification an effective and affordable strategy.

Hidden Hunger in LAC

Globally, micronutrient deficiencies (MND), also known as Hidden Hunger, are the most widespread form of malnutrition, with over two billion people affected. They generally result from inadequate intake and losses due to insufficient food intake, poor quality diets, poor bioavailability of micronutrients in the foods consumed, or frequent infections. MND affect various metabolic processes, resulting in the impairment of sensory and cognitive functions, the weakening of the immune system and ultimately increases morbidity and mortality. Beyond the human factor, the consequences of MND throughout the life cycle result in low productivity and net economic losses for households, communities and nations. In 2012, The Copenhagen Consensus (a group of leading economists and development experts) identified micronutrient interventions as among the top ten most cost-effective actions for development. Clearly there is a moral imperative to tackle MND, but doing so also makes good economic sense.

In LAC, significant economic progress has been made in the past decade, resulting in improvements in the health and nutritional status of populations. Since the 1940s pioneering policies and programs aimed at eradicating MND – such as the fortification of sugar with vitamin A in Guatemala – have been developed and implemented. Today they are still models for other countries. Nonetheless, MND remain pervasive throughout the region. The most prominent problem remains anemia in children and women of reproductive age, of which about half is estimated to be due to iron deficiency, according to the World Health Organization. In the region, anemia is a public health problem in 16 out of 17 countries for women of reproductive age and in 15 countries for children under the age of five. Other deficiencies such as zinc, iodine, vitamin A, folate and vitamin B_{12} are widespread or affect specific vulnerable groups, requiring public health action.

Scaling up rice fortification now

Today, six countries globally have passed legislation for the mandatory fortification of rice, including three in Central America (Honduras, Costa Rica and Panama). However, the law is effectively implemented only in Costa Rica at the moment. In August 2016 the Government of the Dominican Republic and the World Food Programme (WFP) jointly organized the First Forum for the Scaling up of Rice Fortification in Latin America and the Caribbean. This *Sight and Life* supplement participates in that effort. In this publication you will find a comprehensive overview of why fortifying rice with multiple micronutrients can be part of an affordable, effective strategy to increase the intake of essential vitamins and minerals in countries and reduce the prevalence of conditions that result from them, such as chronic undernutrition. This issue is a compilation of original articles from leading public health professionals, as well as articles from the supplement on Scaling Up Rice Fortification in Asia published in 2015 in collaboration between *Sight and Life* and the WFP.

We hope that you will find in it the inspiration to redouble efforts to scale up rice fortification in the Latin American and Caribbean region.

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A young boy looking forward to eating his lunch, Nicaragua 2014

Current Situation of Micronutrients in Latin America and the Caribbean:

Prevalence of Deficiencies and National Micronutrient Delivery Programs

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Technical report prepared for regional consultation organized by the World Food Programme

Introduction

Micronutrient deficiencies are usually more prevalent in developing countries, and are usually the result of inadequate or insufficient food intake, low nutritional quality of the diet, and/or low bioavailability of micronutrients, among other factors. These deficiencies can have multiple negative consequences during the course of the life cycle of individuals, including effects on growth and development of the child and her survival. In recent decades, numerous efforts have been carried out in Latin America and the Caribbean to prevent and control micronutrient deficiencies. Even as the region's epidemiologic and nutritional profile has undergone rapid changes,[1] characterized by an increase in the prevalence of overweight and obesity, the deficiency of some micronutrients persists, especially among the most economically, geographically or socially vulnerable groups.[2]

> "Iron deficiency is one of the most prevalent nutrition deficiencies globally"

Iron deficiency

Iron deficiency is one of the most prevalent nutrition deficiencies globally.[3] This condition affects millions of individuals during the life cycle, especially infants (6–24 months) and pregnant women, but also children, adolescents and women of childbearing age.[4] Iron deficiency negatively affects the neurological development of children,[5,6] increases maternal and infant mortality, and reduces physical work capacity in adults.[7–9] Iron deficiency usually occurs when its intake is insufficient and/or losses are high for a period of time, which can eventually lead to anemia. Anemia is defined as a decrease in the concentration of red cells in blood circulation or of hemoglobin concentration and a concurrent decrease in oxygen-carrying capacity.

The process occurs in three phases: **1)** reduction of stored iron, which is used to keep the body running the vital functions that require this mineral, and which is biochemically characterized by low serum ferritin concentration, the protein that stores iron in the liver; **2)** if iron intake continues to be insufficient, the stored iron is depleted and, therefore, the supply of iron to the tissues is also diminished, which is evidenced biochemically by increased levels of zinc protoporphyrin and transferrin receptor and a reduction in transferrin saturation; and **3)** finally, reduced hemoglobin synthesis is observed, leading to anemia.[10] Anemia can also result from a folate and/or vitamin B_{12} deficiency, hematological disorders, certain genetic conditions, infections, inflammations, among other factors,[11,12] while certain infectious diseases, such as malaria, can exacerbate anemia.[13] The World Health Organization (WHO) estimates that half of all anemia is caused by iron deficiency.[14] According to a WHO estimate of 1993–2005, 25% of the global population has anemia, reaching a prevalence of 47.4% in preschool children, 41.8% among pregnant women and 30.2% in non-pregnant women.[4]

A group of adolescent school girls in Haiti. Reaching adolescent girls with iron and folic acid will not only help them perform better in school, but also help the world reach the new global nutrition targets.

Iodine deficiency

Despite the many efforts to control iodine deficiency, primarily through salt fortification, this condition remains prevalent worldwide.[15] Iodine is essential for the production of thyroxine (T4) and 3,5,3'-triiodothyronine (T3), which are hormones required for normal growth and development of the central nervous system.[16] Iodine deficiency is generally associated with a lower educational level, lower labor productivity and socioeconomic vulnerability,[17] and is considered to be the leading preventable cause of mental retardation globally.[15] Pregnant women, postpartum women and infants are at a higher risk of developing this deficiency. The prevalence of iodine deficiency is commonly estimated by measuring the urinary iodine concentrations of school-aged children, which are then extrapolated to estimate the iodine status in the whole population.[18] In 2007, WHO reported that the overall prevalence of iodine deficiency (median urinary iodine <100 µg/L) was about 35%, affecting approximately 2 billion people, the Americas being the region with the lowest prevalence (9.8%).[15]

> "The consequences of zinc deficiency include growth retardation, hypogonadism, immune dysfunction and cognitive impairment"

Zinc deficiency

The importance of zinc as an essential nutrient for proper human health is well known. Zinc is involved in various pathways of human metabolism, so different metabolic and physiological functions are altered in its absence.[19] In most individuals, zinc deficiency is the result of inadequate dietary intake, malabsorption, increased losses and/or barriers to its utilization. However, in most cases the primary cause of deficiency is an inadequate intake of absorbable zinc, which commonly occurs as a result of the combination of low dietary intake and frequent consumption of foods with low content of this element and/or poorly absorbable forms of zinc.[20] The consequences of this deficiency include growth retardation, hypogonadism, immune dysfunction and cognitive impairment. The diagnosis of zinc deficiency in individuals is not yet possible, since there is currently no indicator with adequate sensitivity and specificity. It is acceptable to use serum zinc levels to assess populations;[21] however, currently few countries include this information in their national nutrition surveys. Therefore, usually indirect indicators, such as the prevalence of linear growth retardation in children <5 years and the intake of absorbable zinc, are used to estimate the risk of deficiency.[21] In Latin America, growth retardation affects up to one third of children less than five years of age, and 30–50% of the population may be at risk of inadequate intake of zinc.[22]

Vitamin A deficiency

Vitamin A deficiency is also very important in terms of public health implications worldwide. Vitamin A deficiency alters various functions in the body and can lead to many negative health consequences, such as a weakened immune system, growth retardation in children, xerophthalmia, an increase in the burden of infectious diseases, and an increase in the risk of death. Xerophthalmia is the most specific consequence of the deficiency and is the leading cause of blindness in children worldwide.[23] Night blindness often appears during pregnancy, a likely consequence of a pre-existing marginal status of this vitamin due to increased nutritional demands during pregnancy and frequent infections. It has been observed that the administration of vitamin A reduces the risk of death in children 6–59 months of age in the range of 23–30%.[24,25] A 2009 WHO report indicated that vitamin A deficiency affected 190 million preschool children and 19.1 million pregnant women who reside in countries with a higher risk of vitamin A deficiency.[23]

Vitamin D deficiency

Vitamin D (calciferol), which consists of a group of fat-soluble sterols, is an essential micronutrient for the homeostasis of calcium and phosphorous.[26] Moreover, new functions of vitamin D on health have been discovered, primarily through research on how its nuclear receptor can mediate control of target genes.[27] Human beings obtain vitamin D from two main sources: photosynthesis in the skin by the action of solar ultraviolet B rays, and dietary intake. Vitamin D can be found naturally in many forms, but the two major physiologically relevant forms for humans are vitamin D_2 (ergocalciferol), derived from plant sources, and vitamin D_3 (cholecalciferol), synthesized in the skin and obtained from animal sources. Vitamin D deficiency is characterized by inadequate mineralization and demineralization of the skeleton. In children it causes rickets, and in adults can precipitate and exacerbate osteopenia, osteoporosis and bone fractures.[26] Studies have shown that vitamin D therapy increases muscle strength in deficient subjects.[28,29] Results of epidemiological studies have linked vitamin D deficiency with an increased risk of certain common cancers, autoimmune diseases, hypertension and infectious diseases.[30–33] The concentration of plasma 25-hydroxyvitamin D (25-OHD) has been regularly used to identify people at risk of vitamin D deficiency and, on a population basis, to consider the adequacy of vitamin D distribution. However, there is currently no overall consensus on the cutoff to define the state of vitamin D.[34] Vitamin D deficiency has the potential to be a public health problem.[35] The magnitude of this deficiency in Latin America is unknown.

Folate and vitamin B_{12} deficiency

Folate and vitamin B_{12} share functions and metabolic pathways, which define the reserve of methyl donor groups used in multiple metabolic routes such as DNA methylation and nucleic acid synthesis.[11,36] Folate is found naturally mainly in vegetables, while folic acid is used in fortified foods.[37] Low levels of folate increase the risk of neural tube defects, which is why folic acid intake is critical before gestation and during the first weeks of pregnancy, when the neural tube closure occurs.[38–40]

Vitamin B_{12} in its natural form is only present in animal foods, so that the deficit is more common among populations with low intake of these foods and vegans.[41] The absorption of vitamin B_{12} from food is lower in older adults, who are at increased risk of gastric atrophy, altered production of intrinsic factor, and acid secretion, all necessary for the proper absorption of this vitamin.[41] The deficiency of both vitamins is associated with hematological disorders.[42] Vitamin B_{12} deficiency can also lead to clinical and subclinical neurological disorders and other disorders in the absence of a hematological deterioration.[43] Therefore, folate and vitamin B_{12} deficiencies have the potential to be considered a public health problem. In 2004 a review estimated the prevalence of deficiency of both vitamins in America, finding that at least 40% of the population had a deficiency or marginal vitamin B_{12} status, while folate deficiency was less common.[44]

> "Latin America has a long history of implementing policies and programs to eradicate micronutrient deficiencies"

Other micronutrient deficiencies

Generally there is little information on the nutritional status of populations regarding other micronutrients essential to wellbeing, such as copper, selenium, vitamin E, vitamin K, thiamin, niacin, riboflavin, biotin, pyridoxine and vitamin C.

Latin America has a long history of implementing policies and programs to eradicate micronutrient deficiencies, and as a result of these, the prevalence of many of these deficiencies has been reduced. However, many gaps still exist and in many cases the deficiencies are still public health problems in the region. Considering the above, the objectives of this review are **1)** to describe the prevalence of micronutrient deficiencies in the region, taking as reference the results of a recent systematic review by our group;[52] **2)** describe existing country programs dedicated to the prevention of these deficiencies; and **3)** briefly discuss the immediate requirements for closing the gaps between the epidemiological data and the program data.

Methodology

Systematic review to determine prevalence of micronutrient deficiency in Latin America

The methodology used in the systematic review has been published in detail.[45–49] Briefly, the databases available on deficiencies of vitamins and minerals were accessed to search for the latest National Health Survey for each country. This information was complemented by accessing the web pages of the Ministries of Health and/or the National Office of Statistics to determine whether the databases mentioned were up to date. Additionally, full searches were carried out of research articles published in PubMed, LILACS and SciELO. We also conducted a search of other relevant documents that could contain information not found in the other searches.

The main indicators and parameters used by surveys and studies selected for the review to determine deficiencies were: serum retinol for vitamin A, 25-OHD levels for vitamin D, serum α-tocopherol for vitamin E, serum ascorbic acid for vitamin C, serum thiamine for thiamine, erythrocyte glutathione reductase (EGRAC) for riboflavin, erythrocyte activity of aspartate aminotransferase (EAAT) for vitamin B_6, serum folate and red cell folate for folate, vitamin B_{12} in serum or plasma, serum copper, urinary iodine, serum or capillary hemoglobin for anemia, serum ferritin for iron, serum selenium and/or erythrocyte and serum zinc.

The cutoffs used for deficiency, insufficient and/or inadequate levels varied widely among studies. However, for some micronutrients classifications with similar cut-off points were identified: lack of vitamin A as retinol < 20 µg/dL and insufficiency as 20.0–29.9 µg/dL; vitamin D deficiency as 25-OHD <25 nmol/L, insufficiency as 25–50 nmol/L and inadequacy as 50–75 nmol/L; vitamin C deficiency as ascorbic acid <0.2 µg/dL; thiamine deficiency <1.25 µg/dL; folate deficiency as serum folate <3.2 ng/mL or RBC folate <181 nmol/L; vitamin B_{12} deficiency as serum vitamin B_{12} <148 pmol/L and marginal levels between 148–221 pmol/L; anemia as hemoglobin <11.0 or <12.0 or <13.0 g/dL; deficiency in iron reserves in the form of serum <12 ferritin or <15 or <20 g/L; mild iodine deficiency as urinary iodine 50–99 g/L, moderate between 20–49 mg/L and severe <20 g/L; zinc deficiency as serum zinc <65 or <70 µg/dL. Reported units were standardized to facilitate comparisons.

The magnitude of the public health problem of deficiency of each micronutrient was defined according to the following cut-off points in prevalence: **1)** anemia (iron), ≤ 4.9%, not a public health problem; 5%–19.9%, mild; 20%–39.9%, moderate; ≥ 40%, severe, according to WHO recommendations;[50] zinc, no problem < 20%, problem > 20%, according to international recommendations;[21] vitamin A, no problem < 2%, mild ≤ 2% to <10%, moderate ≤10% to < 20%, and severe ≥ 20%, according to WHO recommendations;[23] vitamin D, no problem < 5%, 5–19.9% mild, 20–39.9% moderate and ≥ 40% severe;[45] folate, no problem < 5% and problem > 5%; and vitamin B_{12}, no problem < 5% and problem > 5%.

A boy eats his lunch in Nicaragua

Identification of national prevention programs in Latin America

The information presented is based on a recent systematic review of nutrition policies and programs in Latin America and the Caribbean conducted by the Pan American Health Organization and the Micronutrient Initiative.[51]

Results

Prevalence of micronutrient deficiencies in Latin America and the Caribbean

A total of 25 nationally representative surveys and studies were found (**Table 1**) which reported data of the nutritional status of iron (anemia), zinc, vitamin A, vitamin D, folate and/or vitamin B_{12}, mainly in children under 6 years of age (**Table 2**) and women of childbearing age (**Table 3**). The surveys were conducted between 2000 and 2010.

Iron and anemia

According to the latest information available in children (**Table 2**), anemia is not a public health problem in Chile and Costa Rica (<5%). Countries such as Argentina and Mexico have made progress, with anemia in children being a mild public health problem (<20%). In Nicaragua, Brazil, Ecuador, El Salvador, Cuba, Colombia, the Dominican Republic, Peru, Panama and Honduras, anemia in children remains a moderate public health problem (20–40%). In Guatemala, Haiti and Bolivia, anemia in children is a serious public health problem, with prevalence rates above 40%.

Anemia in women of childbearing age (**Table 3**) is not a public health problem (<5%) in Chile, while in Colombia, El Salvador, Costa Rica, Nicaragua, Ecuador, Mexico, Peru, Honduras and Argentina it is a mild public health problem (<20%). Nevertheless, in Guatemala, Brazil, the Dominican Republic and Bolivia it is a moderate public health problem (20–40%), and in Panama and Haiti it is a severe public health problem (> 40%).

Zinc

In the four countries with representative data for plasma zinc, it is observed that the prevalence of zinc deficiency is above 20% in children under 6 years of age in Mexico, Ecuador, Guatemala and Colombia and in women of childbearing age in Mexico and Ecuador. Countries with the highest risk of zinc deficiency – the risk of deficiency was estimated from the prevalence of inadequate zinc intake in the population and the prevalence of stunting in children <5 years, defining high risk as a prevalence of inadequate intake > 25% coupled with a prevalence of stunting > 20% – were Belize, Bolivia, El Salvador, Guatemala, Haiti, Honduras, Nicaragua and Saint Vincent and the Grenadines.[47]

Vitamin A

A total of 10 national surveys and six representative studies were identified. Guatemala and Nicaragua have virtually eradicated vitamin A deficiency (<20 μ g/dL) in children less than 6 years of age (**Table 2**). In Costa Rica, Cuba, El Salvador and Panama, vitamin A deficiency ranges from 2.8–9.4%, representing a mild public health problem (<10%). In Peru, Honduras, Argentina, Ecuador and Brazil, the range varies between 14.0–17.4%, being classified as a moderate public health problem (10–20%), while in Colombia, Mexico and Haiti there is a

TABLE 1: National surveys in Latin America that include data on micronutrient status of population

Country	Year	Survey
Argentina	2004–05	Encuesta Nacional de Salud y Nutrición, 2004–05
Argentina	2007	Encuesta Nacional de Salud y Nutrición, 2007
Bolivia	2003	Encuesta Nacional de Demografía y Salud, 2003
Bolivia	2008	Encuesta Nacional de Salud y Nutrición, 2008
Brazil	2006	Encuesta Nacional de Demografía y Salud en Niños y Mujeres, 2006
Chile	2003	Encuesta Nacional de Salud, 2003
Chile	2009–10	Encuesta Nacional de Salud, 2009–10
Colombia	2005	Encuesta Nacional de Salud y Nutrición, 2005
Colombia	2010	Encuesta Nacional de Salud y Nutrición, 2010
Costa Rica	2006	Encuesta Nacional de Salud, 2006
Costa Rica	2008	Encuesta Nacional de Salud, 2008
Ecuador	2004	Encuesta Nacional de Demografía y Salud en Niños y Mujeres, 2004
El Salvador	2008	Encuesta Nacional de Salud Familiar, 2008
Guatemala	2008–9	V Encuesta Nacional de Salud Materno-Infantil Guatemala, 2008–2009.
Guatemala	2009–10	ENMICRON–II Encuesta Nacional de Micronutrientes, 2009–2010
Honduras	2005–6	Encuesta Nacional de Demografía y Salud, 2005–2006
Honduras	2009	Situación Actual de la Seguridad Alimentaria y Nutricional en Honduras, 2009
Mexico	1999	Encuesta Nacional de Nutrición, 1999
Mexico	2006	Encuesta Nacional de Salud y Nutrición, 2006
Nicaragua	2000	Encuesta Nacional en Micronutrientes, 2000
Nicaragua	2003–5	Encuesta Nacional de Salud Nicaragua, 2003–2005
Panama	2000	Estudio Nacional de Deficiencia de Hierro y Vitamina A, 1999–2000
Panama	2006	Situación Nutricional, Patrones Dietarios, y Acceso Alimentario en Panamá, 2006
Peru	2010	Encuesta Familiar de Demografía y Salud, 2010
Rep. Dominicana	2007	Encuesta Nacional de Demografía y Salud, 2007
Uruguay	2007	Encuesta de Lactancia, Estado Nutricional y Alimentación Complementaria, 2007

TABLE 2: Prevalence of micronutrient deficiencies and magnitude of public health problem in children less than 6 years of age in Latin American countries with representative data[a]

Public health problem[a]		Anemia	Zinc	Vitamin A	Vitamin D	Folate
No		Chile 2012 (4%)		Guatemala 2009–10 (0.3%)	Mexico 2006	Mexico 2006
problem		Costa Rica 2009 (4%)		Nicaragua 2005 (0.7%)	(<1%)[b]	(3.2%)
	Mild	Chile 2013 (14.0%)		Costa Rica 2009 (2.8%)		
		Argentina 2007 (16.5%)		Cuba 2002 (3.6%)		
				El Salvador 2009 (5.0%)		
				Panama 2000 (9.4%)		
	Moderate	Nicaragua 2003–05 (20.1%)				
		Brazil 2006 (20.9%)				
		Mexico 2006 (23.7%)				
		Ecuador 2012 (25.7%)	Mexico 2006 (27.5%)	Peru 2001 (13.0%)		
Problem		El Salvador 2008 (26.0%)	Ecuador 2013 (28.8%)	Honduras 1999 (14.0%)		
		Cuba 2011 (26.0%)	Guatemala 2010 (34.9%)	Argentina 2007 (14.3%)		
		Colombia 2011 (27.5%)	Colombia 2010 (43.3%)	Ecuador 2013 (17.1%)		
		Rep. Dominicana 2009 (28.0%)		Brazil 2006 (17.4%)		
		Peru 2012 (32.9%)				
		Panama 2000 (36.0%)				
		Honduras 2005 (37.3%)				
	Severe	Guatemala 2009 (47.7%)		Colombia 2010 (24.3%)		
		Bolivia 2008 (61.3%)		Mexico 1999 (26.2%)		

[a] Cut-off points used to determine severity of public health problem according to prevalence: Anemia: no problem ≤4.9%, mild 5–19.9%, moderate 20–39.9%, severe ≥40%; Zinc deficiency: no problem < 20%, problem >20%; Vitamin A deficiency: no problem <2%, mild ≤2% to <10%, moderate ≤10% to <20% and severe ≥20%; Vitamin D deficiency: no problem <5%, mild 5–19.9%, moderate 20–39.9%, severe ≥40%; Folate deficiency: no problem <5%, problem >5%.

[b] Prevalence of insufficiency: 24% in preschool children and 10% in school-aged children.

severe problem (> 20%). It is important to note that the highest prevalence of deficiency is among children from indigenous communities. When assessing the change in the prevalence in those countries with more than one survey, a significant reduction in vitamin A deficiency is observed in countries in Central America, while in South American countries the deficiency has increased over time.[48]

In women of childbearing age in El Salvador and Nicaragua, vitamin A deficiency is not a public health problem, while in Mexico and Peru there is a mild problem, and in Brazil it is moderate (**Table 3**).

3.1.4 Vitamin D

The exact magnitude of the inadequacy of vitamin D in the region is unknown. Only Mexico has representative data on children. Overall, 54.0% of Mexican children present vitamin D inadequacy, with a prevalence of deficiency and insufficiency in preschool children of 24% and 30%, respectively, and a prevalence of deficiency and insufficiency in school-aged children of 10% and 18%, respectively. Some countries have data on the prevalence of vitamin D deficiency in children from non-representative studies, such as Colombia (10–12%),[52,53] Brazil (9%),[54] Argentina (3%),[55] and more recently Chile, with data for preschool children in southern areas (64%).[56]

3.1.5 Folate and vitamin B_{12}

The few available national data for folate generally show a prevalence of deficiency lower than 5% in different population groups (**Tables 2 and 3**). Mexico reports a prevalence of 3.2% in children less than 6 years of age. In Argentina, only 2.7% of pregnant women and 1.3% of women of childbearing age are deficient, while in Costa Rica and Chile 1.4% and 0.6%, respectively, of older adults are deficient. When comparing with earlier data, a significant reduction in the prevalence of folate deficiency is observed in the region; this can be attributed to existing universal folic acid fortification programs, which in some countries is also associated with a reduction in neural tube defects.[57]

In the case of vitamin B_{12}, only a few countries have national data. In Mexico, 5.5% of preschool children and 8.5% of adult women have serum levels considered to be low (<148 pmol/L). In Costa Rica, 4.8%, 6.4%, 2.9% and 5.3% of women of childbearing age, adult women, adult men, and elderly, respectively,

A young girl in Bolivia. Approximately 80% of children in Bolivia under the age of two are anemic. Chispitas – a multimicronutrient powder that contains iron – is a weapon in the fight against childhood anemia.

had low serum levels. In Colombia, the prevalence of marginal serum vitamin D_3 levels (<221 pmol/L) was 21.0%, 59.9% and 37.3% among children under 18, pregnant women and women of childbearing age, respectively. In Argentina, 49.1% of pregnant women and 11.9% women of childbearing age had marginal serum levels. It is difficult to draw conclusions regarding the deficiency of folate and vitamin B_{12} due to lack of consensus on the cut-off points to distinguish between normal and deficient.

3.2 National micronutrient delivery programs in Latin America

Table 4 describes the various micronutrient supplementation and fortification programs that are currently implemented at national level in the region and the number of countries that have adopted each of these strategies. Ninety percent (90%)[18,20] of countries in the region indicate having iron supplementation programs for pregnant women, fortification of salt with iodine and fortification of wheat flour with iron and one or more vitamins. Eighty percent (80%) of countries indicate having at least one program providing iron supplements to children 6–59 months of age, while 75% indicate having a program to deliver vitamin A supplements to children 6–59 months old and 60% having a program that delivers multiple micronutrient powders for home food fortification. Only five countries (25%) indicate providing zinc supplements for the treatment of diarrhea in children less than 5 years of age. Similarly, 25% of the countries in the region indicate implementing mass fortification of sugar with vitamin A and of corn flour with iron and at least one other micronutrient. Finally, according to the data most recently collected, only Costa Rica, Nicaragua and Panama report having a universal rice fortification program; however, only Costa Rica is currently implementing it.

TABLE 3: Prevalence of micronutrient deficiencies and magnitude of public health problem in women of reproductive age in Latin American countries with representative data[a]

Public health problem[1]		Anemia	Zinc	Vitamin A	Folate
No problem		Chile 2003 (5.1%)		El Salvador 2009 (1.0%) Nicaragua 2000 (1.3%)	Costa Rica 2008 (3.8%) Argentina 2007 [pregnant women] (2.7%) Argentina 2007 [adolescents and women] (1.3%)
Problem	**Mild**	Colombia 2010 (7.6%) El Salvador 2008 (10.0%) Costa Rica 2009 (10.2%) Nicaragua 2003-05 (11.2%) Ecuador 2012 (15.0%) Mexico 2006 (15.5%) Peru 2012 (17.7%) Honduras 2005 (18.7%) Argentina 2007 (18.7%)	Mexico 2006 (28.1%) Ecuador 2013 (56.1%)	Mexico 1999 (4.3%) Peru 2001 (8.7%)	
	Moderate	Guatemala 2009 (21.4%) Brazil 2006 (29.4%) Rep. Dominicana 2002 (34.0%) Bolivia 2008 (38.3%)		Brazil 2006 (12.3%)	
	Severe	Panama 2000 (40.0%)			

[a] Cutoff points used to determine severity of public health problem according to prevalence: Anemia: no problem ≤4.9%, mild 5–19.9%, moderate 20–39.9%, severe ≥40%; Zinc deficiency: no problem < 20%, problem >20%; Vitamin A deficiency: no problem <2%, mild ≤2% to <10%, moderate ≤10% to <20% and severe ≥20%; Vitamin D deficiency: no problem <5%, mild 5–19.9%, moderate 20–39.9%, severe ≥40%; Folate deficiency: no problem <5%, problem >5%.

Smiling girls having a school meal in Honduras

TABLE 4: National programs that provide micronutrients in Latin America, as reported by countries

Program	Target group	No. Countries (%)[a]	Countries
Supplementation[b]			
Supplementation with vitamin A	Children 6–59 m	15 (75)	Argentina, Belize, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, Dominican Republic
Supplementation with iron	Children 6–59 m	16 (80)	Argentina, Belize, Bolivia, Brazil, Chile, Costa Rica, Peru 2001 (8.7%), El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay
Multiple micronutrient powders for home fortification of foods	Infants 6–23 m	12 (60)	Argentina, Bolivia, Brazil, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Peru, Dominican Republic, Uruguay
Supplementation with iron and folic acid	Women of fertile age	7 (35)	El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Dominican Republic
	Pregnant women	18 (90)	Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay
Supplementation with calcium	Pregnant women	3 (15)	Colombia, El Salvador, Nicaragua
Supplementation with zinc for treatment of diarrhea	Children 0–59 m	5 (25)	Bolivia, Colombia, El Salvador, Guatemala, Nicaragua
Universal food fortification[c]			
Salt (iodine)	All	18 (90)	Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay
Sugar (vitamin A)	All	5 (25)	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua
Wheat flour[c]	All	18 (90)	Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, Uruguay
Maize flour[d]	All	5 (25)	Brazil, Costa Rica, El Salvador, Guatemala, Mexico
Rice[e]	All	3 (15)	Costa Rica, Nicaragua, Panama

[a] Total number of countries = 20

[b] Source: Tirado MC et al. [51]

[b] Source: Flour Fortification Initiative. *www.ffinetwork.org/global_progress/index.php*

[c] All countries fortify with iron, thiamin, riboflavin, niacin and folic acid, except Brazil (iron and folic acid), Cuba (also includes vitamin B_{12}), Mexico (iron and folic acid), Uruguay (iron, folic acid and vitamin B_{12}) and Venezuela (iron, thiamin, riboflavin and niacin).

[d] Different formulations used among countries: Brazil (iron and folic acid), Costa Rica and El Salvador (iron, thiamin, riboflavin, niacin and folic acid), Guatemala (iron, zinc, thiamin, riboflavin, niacin, folic acid and vitamin B_{12}), Mexico (iron, zinc, thiamin, riboflavin, niacin and folic acid) and Venezuela (iron, riboflavin, niacin and vitamin A).

[e] Nicaragua and Panama fortify with iron, zinc, riboflavin, niacin, folic acid and vitamin B_{12}; Costa Rica with zinc, thiamin, riboflavin, niacin, folic acid and vitamin B_{12}. Costa Rica is only country with implemented, ongoing program.

A young child in Haiti receives a dose of vitamin A. For populations deficient in vitamin A, twice-annual doses boost immunity and help protect against preventable childhood diseases.

Discussion: Analysis of the immediate needs to close the gaps

Over the last decade, Latin America has experienced significant economic growth, which has had an impact on the health and nutrition status of the population. For example, the prevalence of chronic malnutrition (stunting) in children has decreased from 13.7% in 1990 to 6.2% in 2015,[58] and between 1995 and 2011 hemoglobin concentrations in women increased more in Andean and Central American countries than in other regions of the world.[59] However, despite these advances, the data collected shows that there are still gaps in Latin America for populations to have an optimal micronutrient status. Anemia remains a public health problem in children and women of childbearing age in most countries for which data are available. The exact magnitude of zinc deficiency is unknown – no representative data of serum zinc is available in most countries – although a high prevalence of stunting in children under five and inadequate zinc intake is observed at population level, both indicating that there is a high risk of deficiency of this micronutrient.[47] Vitamin A deficiency has declined significantly in several countries, especially in Central America, although in other countries not only does it continue to be a moderate to severe problem in children under six years, but also the trend in recent years is on the rise.[48] It can be suspected that vitamin D deficiency is a public health problem in the region, but current data do not reveal its magnitude. Folate deficiency is almost non-existent, but a high prevalence of low or marginal vitamin B_{12} status is observed in most countries and in most population groups. Additionally, it is important to note that the data presented do not consider the inequity that is known to exist in the different geographical areas of the country, with the problem being most severe in rural areas, and/or according to ethnicity, being greater among indigenous communities.

> "There are still gaps in Latin America for populations to have an optimal micronutrient status"

Figure 1 shows the number of micronutrient deficiencies in children under six years of age that are considered to be a public health problem, by country, taking into account only those countries reporting national data. Mexico has four micronutrients for which the deficiency is considered a public health problem (iron, based on presence of anemia, zinc, vitamin A and vitamin D), while for Colombia and Ecuador it would be the case for three micronutrients (iron, zinc, vitamin A). In Guatemala (iron, zinc) and Honduras, Peru and Brazil (iron, vitamin A) two micronutrient deficiencies are a public health problem, and in Argentina (vitamin A), Bolivia, Panama, Dominican Republic, Salvador and Nicaragua (iron) only one micronutrient deficiency is considered a public health problem. Finally, in Chile and Costa Rica, micronutrient deficiencies are apparently not a public health problem.

It is important to note that a gap itself is the lack of available or up-to-date information in Latin America for micronutrient deficiencies. Between 60% and 70% of the countries in the region do not have representative data on the prevalence of anemia in children, women of childbearing age and/or pregnant women in the period between 1985 and 2014.[60] Among those countries that do have information, only about 20% have data for two periods of time, and 65% of the available information is outdated by 10 or more years. Similarly, 60–90% of countries don't have representative data for vitamin A, iron, iodine, folate and/or vitamin B_{12}.[60] Closing micronutrient gaps will remain difficult if estimates of their prevalence are not regularly carried out to first allow a diagnosis of the status of the population and then set desired goals and evaluate the progress achieved.

Figure 2 shows the number of national-level programs that deliver micronutrients for each country in the region. It can be observed that all countries in the region have at least five national micronutrient delivery programs. Most countries provide iron supplements to pregnant women and children 6–59 months of age and provide vitamin A supplements to children less than

FIGURE 1: Number of micronutrient deficiencies in children under the age of six considered moderate or severe public health problems in Latin America, according to the most recent national data available

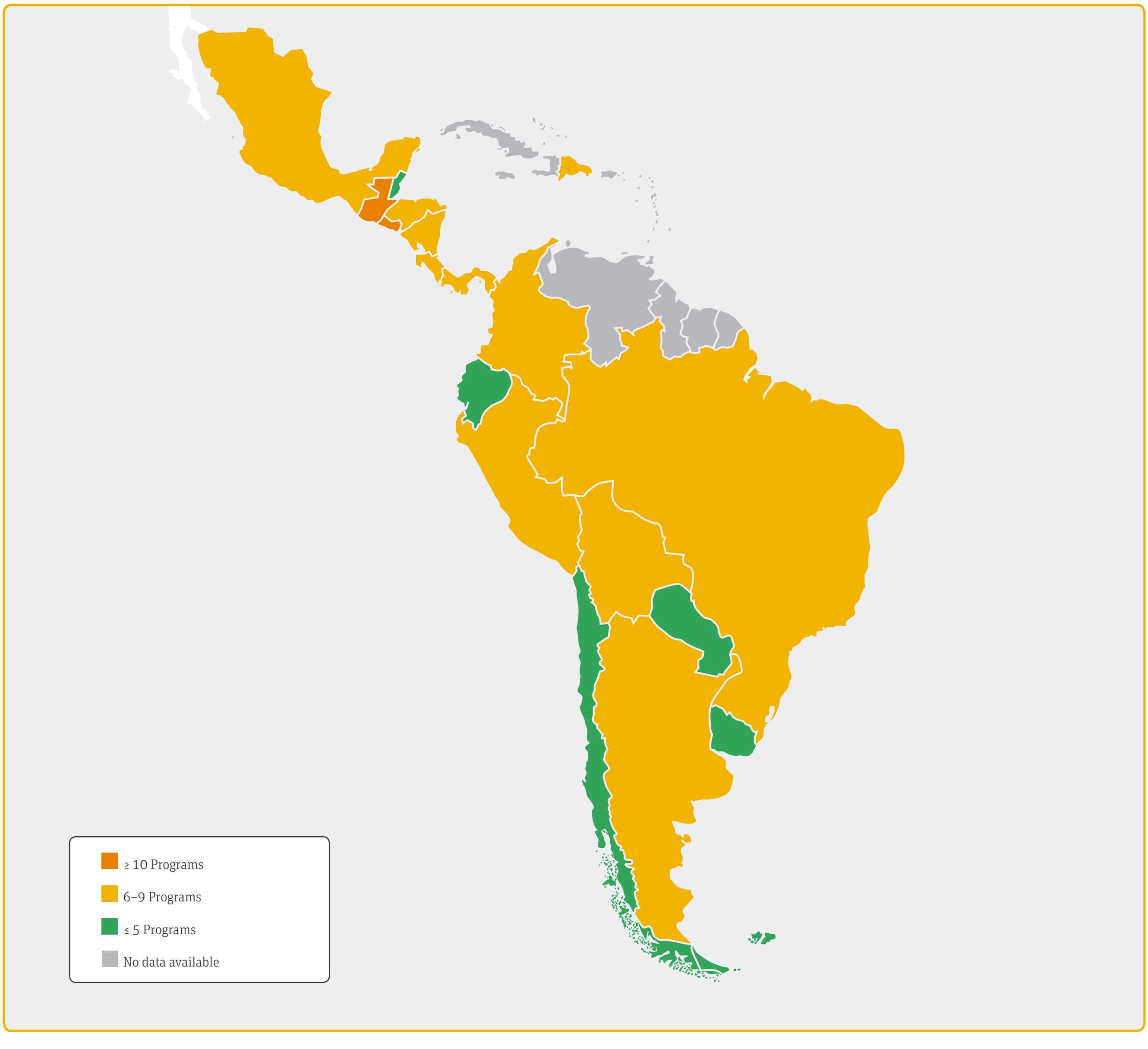
five years of age. Most countries fortify wheat flour with iron and at least one other micronutrient. The first question that arises is, if countries implement these programs, why do certain micronutrient deficiencies persist among women and children? A number of weaknesses in these programs can be identified that might address the query above. First, for example, although not much systematized data exists for the region, it is known that micronutrient supplementation programs have low coverage, usually due to several factors, such as: **1)** difficulty in accessing micronutrient distribution systems by users; **2)** problems in the acquisition, distribution, monitoring, quality control and storage of micronutrients; and **3)** limitations at the point of delivery of micronutrients (knowledge of staff). Second, limitations in the knowledge of users, or of their caregivers, regarding both the benefits of micronutrients and of the programs themselves. Finally, limitations in the intake of micronutrients that are delivered by the program (either supplement or fortified product). In addition, unfortunately there are very few available published reports or scientific studies reporting either the coverage of programs or their use by the target population and/or reporting the biological impact of these programs on the population that would permit an in-depth understanding of the extent of the limitations previously described and facilitate the implementation of specific actions to overcome these barriers within each context.

To summarize, certain actions are required to further reduce micronutrient deficiencies in Latin America. For example, representative data on the prevalence of deficiencies is required, collected either annually, biannually or every five years, to assess and redefine, if necessary, policies and programs currently delivering micronutrients nationwide. In addition, an analysis of the capabilities countries currently possess to optimize ongoing programs and, thus, allow them to be more effective, is necessary. Another alternative is to evaluate, in parallel with actions to optimize existing programs, the implementation of other strategies to close the gap regarding the status of micronutrients in the region. One possible strategy is the fortification of rice with one or more micronutrients in countries where this strategy is deemed feasible. For this, a prior analysis of the country profile is needed,including a detailed review of the nutritional situation in the country, a description of existing programs, a characterization of the rice industry in the country and a description of the distribution and consumption of rice by different population subgroups and, specifically, the most vulnerable groups, which indicates whether this strategy can help bridge the gap in these countries.

Conclusions

Existing data suggest that in recent years the general prevalence of micronutrient deficiencies in Latin America has declined, although there is a significant gap in terms of the data available. However, in several countries, the deficiency of one or more of these micronutrients remains a public health problem, especially in populations or groups with greater economic, geographical and/or social vulnerability. Ongoing national micronutrient delivery programs in the region can and should be optimized to

FIGURE 2: Number of national programs for delivering micronutrients in Latin American countries



Schoolgirls in the village of Nazareno, Municipality of Tupiza, in the Department of Potosi, Bolivia, eat a meal of rice and beans during lunch in March 2010 be more effective and cost-effective in their management, but studies and analyses are needed to fully understand the limitations governments experience in their capacity to achieve these goals. Finally, in certain countries in the region, ongoing programs could be complemented by other strategies, such as rice fortification, dependent on a prior assessment of the feasibility of implementing this strategy.

> "National micronutrient delivery programs in the region should be optimized to be more effective and cost-effective in their management"

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Introduction to Rice Fortification

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Key Messages

- Where rice is a staple food, and micronutrient deficiencies are widespread, making rice more nutritious by fortifying it with essential vitamins and minerals can make a significant contribution to addressing micronutrient deficiencies and improving public health.
- Decades of experience have proven that large-scale food fortification is a sustainable, safe and effective intervention with significant public health impact.
- Rice fortification, like all other food fortification, should be one intervention within a broad multisectoral strategy to improve micronutrient health.
- Current technology can produce fortified rice that is safe, and that looks, tastes and can be prepared the same as non-fortified rice. Consumption of fortified rice increases micronutrient intake without requiring consumers to change their buying, preparation or cooking practices.
- Large-scale rice fortification is most successful when driven by a multisectoral coalition, which includes national government, the private sector, and civil society organizations.
- Rice fortification has the greatest potential for public health impact when it is mandated and well regulated. When this is not feasible, the fortification of rice distributed through social safety nets is an effective alternative to reach populations who can most benefit.
- The cost of rice fortification is determined by context-specific variables. Thus, it is not possible to calculate a universal cost figure. However, based on experience in 15 countries, four of which are in Asia, the retail price for fortified rice may rise by from 1% to 10%. As rice fortification is scaled up, it will achieve economies of scale, which will reduce costs.

Introduction

Micronutrient deficiencies affect more than two billion people worldwide and are especially prevalent in developing countries. Also referred to as Hidden Hunger, micronutrient deficiencies impair physical growth and cognitive development and have long-term effects on health, learning ability, and productivity. Consequently, micronutrient deficiencies increase morbidity and mortality across the lifespan and have a negative impact on social and economic development.[1]

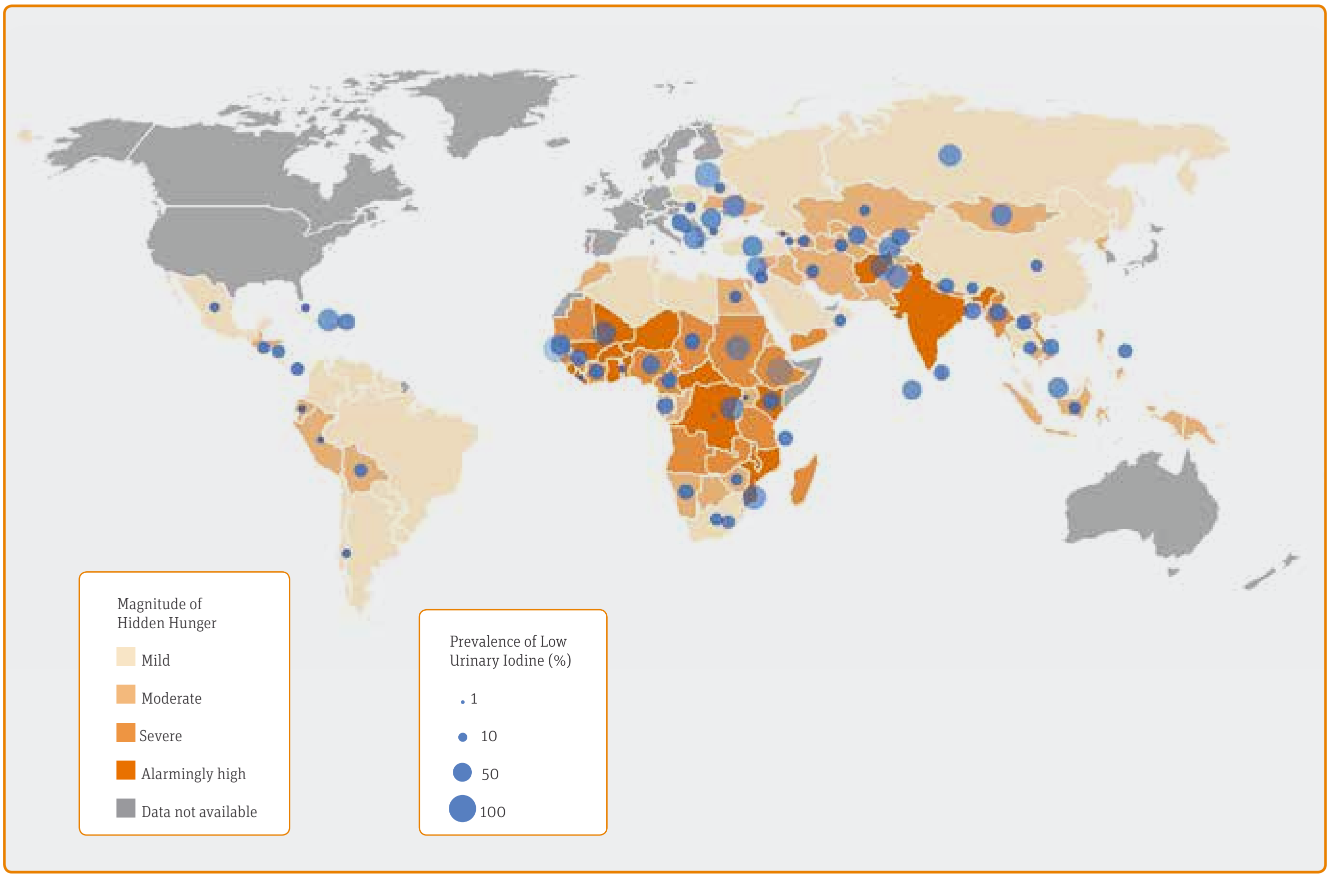
Rice is a staple food for more than three billion people across the globe. In some countries, including Bangladesh, Cambodia and Myanmar, rice contributes as much as 70% of daily energy intake. This presents a nutritional problem: milled rice is a good source of energy, but a poor source of micronutrients.[2] Therefore, where rice is a staple food, making it more nutritious through fortification with essential vitamins and minerals is a proven and cost-effective intervention to increase micronutrient intake among the general population.[3]

> "Rice is a staple food for more than three billion people across the globe"

The Lancet 2008[4] and 2013[5] Maternal and Child Nutrition Series, the Copenhagen Consensus[6] and Scaling Up Nutrition (SUN) Movement all recognize and endorse staple food fortification as a sustainable, cost-effective intervention with a proven impact on public health and economic development. Reducing micronutrient deficiencies and undernutrition has the potential to reduce by more than half the global burden of disability for children under age five, to prevent more than one third of global child deaths per year, and, in Asia and Africa, to boost GDP by up to 11%.[7]

This article provides an overview of large-scale rice fortification, and highlights important considerations for its introduction, implementation and scale-up. For definitions of the terminology presented in this article, please refer to the glossary (p.223).

FIGURE 1: Hidden Hunger Map[11]



Importance of addressing micronutrient deficiencies

Micronutrient deficiencies occur when a diverse and nutrient-rich diet (i.e., one that includes animal-source foods such as meat, eggs, fish, dairy, as well as legumes, cereals, fruits and vegetables) is neither consistently available nor consumed in sufficient quantities. In addition, gut inflammation and illnesses (such as diarrhea, malaria, helminthiasis [worms], TB, and HIV/AIDS) affect a person's ability to absorb micronutrients and can lead to deficiencies. In low- and middle-income countries (LICs and MICs) multiple micronutrient deficiencies tend to coexist, as they share common causes.[5]

Although more prevalent in LICs and MICs, micronutrient deficiencies also represent a public health problem in industrialized nations and in populations suffering from overweight and obesity. The increased consumption of highly processed, energy-dense but micronutrient-poor foods in industrialized countries, and in countries in social and economic transition, is likely to adversely affect their populations' micronutrient intake and status.[1]

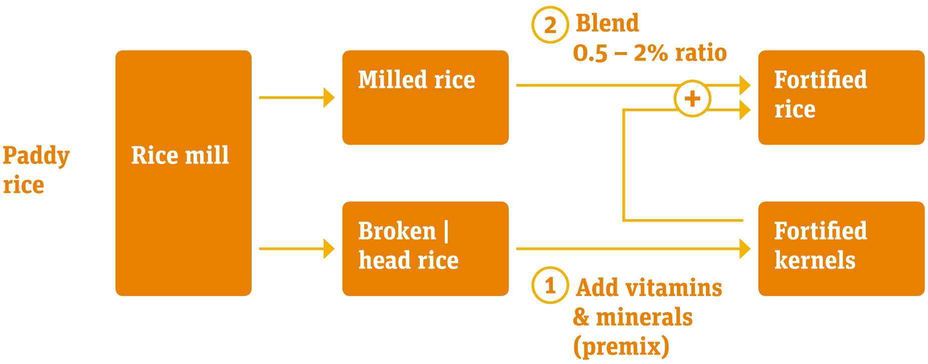
Deficiencies in iron, zinc and vitamin A are the most common types of micronutrient deficiencies, and are among the top ten causes of death through disease in developing countries. In addition, deficiencies in B vitamins, iodine, calcium and vitamin D are also highly prevalent.[1] **Figure 1** demonstrates the global landscape of micronutrient deficiencies, also called Hidden Hunger.

> "Although more prevalent in LICs and MICs, micronutrient deficiencies also represent a public health problem in industrialized countries"

Rice fortification: Cost-effective intervention to improve micronutrient health

While milled rice is a good source of energy, it is a poor source of micronutrients. Therefore, in countries with widespread micronutrient deficiencies and large per capita rice consumption, making rice more nutritious through fortification can effectively increase micronutrient intake.[3] Decades of experience and evidence have proved that large-scale staple food and condiment fortification is a safe and cost-effective intervention to increase vitamin and mineral intake among the general population.

FIGURE 2: Two-step rice fortification manufacturing process



Rice fortification builds upon the global success and long-established evidence base for safe and effective flour and salt fortification programs. Wheat and maize flour have been successfully fortified with iron, folic acid and other micronutrients for more than 60 years. Salt's nearly century-old history of iodine fortification has resulted in a dramatic reduction in global iodine deficiency.

From a regulatory, public health and nutrition point of view, rice fortification is very similar to maize and wheat flour fortification. However, from an implementation and technical perspective, fortifying rice differs significantly from fortifying flour.

Rice fortification, like other food fortification, should be one component of a larger integrated and multisectoral strategy to improve micronutrient health that aims to improve dietary diversity and infant and young child feeding practices. This is because the consumption of fortified foods on their own will fall short of fulfilling micronutrient gaps for groups with relatively high micronutrient needs. For example, target populations such as young children and pregnant or lactating women will require additional micronutrient supplementation to meet their requirements. In addition, improved sanitation, good hygiene practices, and accessible and high-quality preventive and curative health services are essential to sustain a population's good micronutrient health.

In the 1940s, the Philippines began fortifying rice with thiamin, niacin and iron. This resulted in the successful elimination of beriberi, a severe public health problem caused by thiamin deficiency. In 1952, the Philippines pioneered the first mandatory rice fortification legislation requiring all rice millers and wholesalers enrich the rice they milled or traded.[8]

Since these early efforts, the past decade has seen a significant evolution of cost-effective rice fortification technologies that are unlocking opportunities to significantly contribute to the reduction of micronutrient deficiencies. Affordable technology is available to produce fortified rice that looks, smells and tastes the same as non-fortified rice, with its nutrients retained after preparation and cooking. Thus, micronutrient intake can be increased without requiring consumers to change their rice buying, preparation, or cooking practices.

"The past decade has seen a significant evolution of cost-effective rice fortification technologies"

Rice fortification technology and production

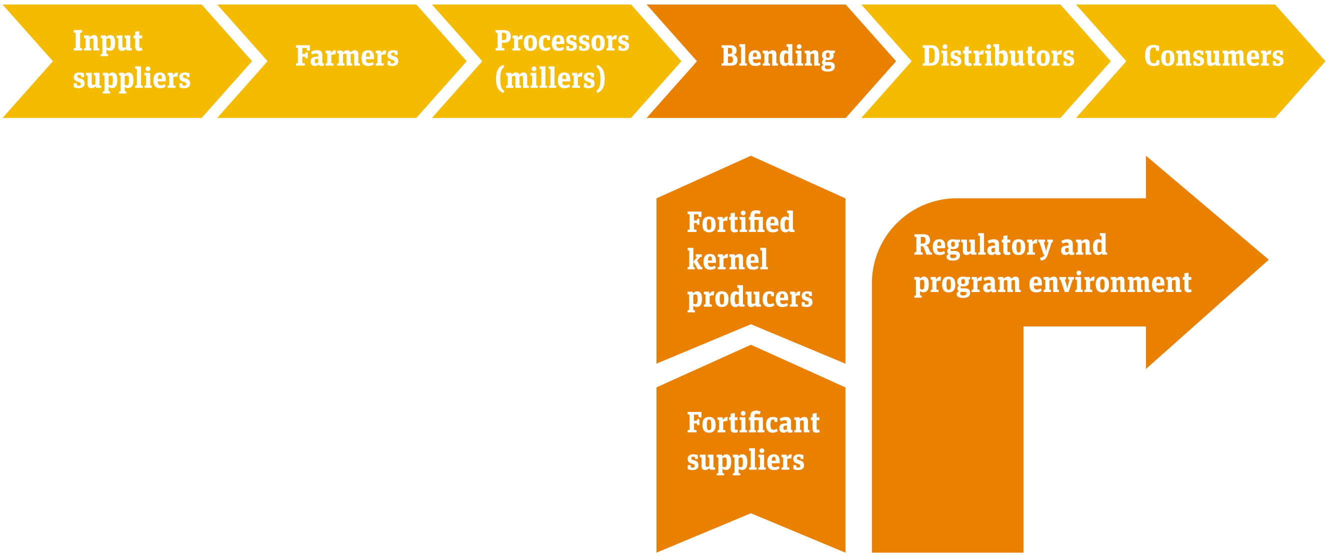
As illustrated in **Figure 2**, rice fortification that retains micronutrients after preparation and cooking includes a two-step process involving the formation of fortified kernels containing appropriate vitamins and minerals, and blending of the fortified kernels with milled rice to create fortified rice.

Extrusion and rinse-resistant coating technologies produce fortified rice that is effective and acceptable to consumers (color, taste and texture). The type of fortificants chosen and the technology used ensure that fortificants remain stable and bioavailable under different conditions of storage, transportation, preparation, and cooking. For additional information on fortification technologies, please refer to the contribution by Montgomery et al (p. 159).

As shown in **Figure 3**, when rice fortification is introduced, the rice supply chain is adapted to incorporate fortified kernel production and blending. This also requires the integration of additional quality assurance, quality control and regulatory monitoring.

Conducting a rice landscape analysis (pp. 199–209) is strongly recommended to determine how to integrate fortified kernel production and blending into the rice supply chain, and to assess the potential health impact. The integration of the

FIGURE 3: Rice fortification supply chain



additional fortification steps has to take into account the following aspects: the structure and capacity of the rice industry; the complexity of the existing rice supply chain; the existing distribution channels; consumer consumption and purchasing preferences; and the policy and regulatory environment. Results of the rice landscape analysis also provide valuable information for strategic decisions regarding the delivery options for fortified rice, which stakeholders to engage, and how to adapt the regulatory and policy environment.

Recommended micronutrients for inclusion in fortified rice

From a public health and nutrition point of view, the research and recommendations related to wheat flour fortification can also be applied to rice fortification. However, it is important to consider the differences between rice and flour in terms of nutrient content and any technological aspects that warrant changes of the recommendations when fortifying rice instead of flour. Based on the evidence available, it is recommended to consider fortification with the following micronutrients: iron, vitamin A, vitamin B9 (folic acid), vitamin B6 (pyridoxine), vitamin B12 (cobalamine), vitamin B1 (thiamin), vitamin B3 (niacin) and zinc.[9] However, the determination of which micronutrients should be included and at what level depends on the target population's micronutrient intake, the prevalence of micronutrient deficiencies, and access to, and consumption of, other fortified foods. Each country introducing rice fortification will need to develop fortification standards, taking into account its local micronutrient situation and existing micronutrient interventions. For additional information on the evidence for recommended micronutrients and standards, please refer to the contributions de Pee et al (Trials, p. 143 and Standards, p. 165).

> "From a public health and nutrition point of view, the research and recommendations related to wheat flour fortification can also be applied to rice fortification"

Target populations for rice fortification

The potential for individuals to benefit from rice fortification varies across the course of a lifetime, and depends on micronutrient requirements, dietary intake, the amount of rice consumed, and the potential of fortified rice to fill micronutrient gaps. For example, women of reproductive age (19–45 years old) have moderate to high micronutrient requirements and consume a significant amount of rice. Therefore, they are likely to consume a sufficient quantity of fortified rice to meet their micronutrient needs. However, pregnant women have increased micronutrient needs. Although the fortified rice they consume will help meet these needs, it is unlikely to fully meet them. Therefore, other interventions such as iron/folate or multiple micronutrient supplementation will still be required. Young children aged 6 to 23 months, likewise, have relatively high micronutrient needs, yet consume only small quantities of rice. Therefore, fortified rice will not be sufficient to fill their micronutrient gap. For

Extruded fortified rice

additional information on specific micronutrient needs across the lifecycle, please refer to **Figure 4** in the contribution by Rudert et al (p. 193).

Potential delivery options for fortified rice

To achieve public health impact, it must be feasible and sustainable to fortify a significant portion of the rice consumed, especially for the target populations that can most benefit from its consumption. Mandatory fortification, in which legislation and regulations require the fortification of all rice to a specific standard, has the greatest potential for public health impact. When fortification is well regulated and enforced, the entire population will consume fortified rice without having to change purchasing or consumption practices. Costa Rica has successfully implemented mandatory rice fortification since 2001. For additional information on Costa Rica's successful experience, please refer to the contribution by Tacsan et al (p. 212).

Mandatory fortification may not always be feasible, due to the structure of the rice industry, the complexities of the rice supply chain, lack of political will, and other contextual factors. Therefore, the fortification of rice distributed through social safety net programs provides an alternative delivery option to reach groups who can most benefit from the consumption of fortified rice. This entails fortifying rice distributed for free, or at a subsidized cost, through school feeding programs, emergency distributions, or other programs that support lower socioeconomic groups.

Voluntary fortification is a market-driven approach in which fortified rice is marketed as a "value-added" product to consumers. This delivery option has limited potential to achieve a significant public health impact, as it relies on consumer awareness, demand generation and the willingness and ability to pay slightly more for the fortified rice. For additional information on delivery options for fortified rice, please refer to the contribution by Codling et al (p. 170).

> "The cost of rice fortification is determined by a multitude of context-specific variables, and thus it is not possible to calculate a universal cost figure"

Cost of rice fortification

The cost of rice fortification is determined by a multitude of context-specific variables, and thus it is not possible to calculate a universal cost figure. The cost of fortified rice will depend upon the structure and capacity of the rice industry, the complexity of the rice supply chain, the policy and regulatory environment, and the scale of the relevant program. However, based on the experience thus far in 15 countries, four of which are in Asia, the retail price increase for fortified rice ranges from an additional 1% to 10%. As rice fortification expands, production and distribution achieve economies of scale and costs are reduced.[10]

During the introductory phase of rice fortification costs will be incurred for mobilizing stakeholder support, conducting a rice landscape analysis, developing a business case, carrying out trials for logistical feasibility and consumer acceptability, policy development, and general project management. The rice landscape analysis will inform strategic decisions regarding the source and production of fortified kernels, blending locations, delivery options, and the scale of operations. During the implementation phase, capital investments will be needed and recurring costs will be incurred for the production and distribution or sale of fortified rice. Recurring costs include fortified kernel production, transportation, blending, quality assurance and quality control, as well as continuing policy development and general project management. In the scale-up phase, fortified rice production and distribution expand. This expansion should result in greater efficiency of the supply chain, and economies of scale.

Conclusion

The number of countries introducing rice fortification is growing, with Asian and Latin American countries spearheading the effort. Fortifying rice, a staple food for more than three billion people globally, has the potential to improve population health, increase productivity, and promote economic development. Rice fortification has benefitted from the experience of wheat and maize flour fortification. Considerations for rice fortification programs include appropriate decisions on the fortificant premix, fortification technology, the supply chain, delivery options, and the regulatory and monitoring environment. The evolution of cost-effective technologies, combined with data on effective nutrient fortification levels, makes rice fortification safe, feasible, effective, and sustainable. Costs are context-specific and, as programs expand, economies of scale will be achieved and costs will decline. Strong advocacy is needed to further drive the public-private partnerships and the government mandates that help ensure long-term success.

The potential impact of improving micronutrient health in Asia, Latin America and beyond is vast. The time is right – there is great momentum to move forward with rice fortification from a growing number of governments, private sector leaders, and key global health organizations. Asia and Latin America can seize the momentum and lead the way in building effective and sustainable rice fortification programs.

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Overview of Evidence and Recommendations for Effective Large-Scale Rice Fortification

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Key Messages

- Multiple efficacy and effectiveness studies have established the impact of fortified rice on micronutrient status.
- To prepare for the introduction of fortified rice, countries should conduct a landscape analysis to assess feasibility and consumer acceptability. Given the existing evidence base, it is not necessary to conduct additional efficacy trials prior to the introduction of rice fortification.
- Based on available evidence of efficacy, stability and needs, the following micronutrients are recommended for rice fortification: iron, zinc, and vitamins A, B_1 (thiamin), B_3 (niacin) B_6 (pyridoxine), B_9 (folic acid) and B_{12} (cobalamin).
- Rice fortification programs should use technology and micronutrient fortificant forms that produce fortified rice that is acceptable to consumers, retains micronutrients during storage and preparation, and releases them for absorption by the body.
- When introducing fortified rice, countries should monitor implementation. This includes appropriate fortification (i.e., of fortified kernels and their blending), storage and distribution, and monitoring of acceptance and consumption.

Introduction

In populations where rice is a major staple food, fortification of rice with micronutrients has the potential to increase micronutrient intake. Decades-long experience with fortification of other staple foods and condiments has proven that large-scale fortification is efficacious. This article discusses country-level considerations for rice fortification and reviews the global evidence base for the efficacy and effectiveness of rice fortification.

Country-level considerations for food fortification

Identifying suitable micronutrients for fortification

An analysis of which micronutrient deficiencies are likely to exist and are of public health significance will help determine which micronutrients should be used to fortify rice, and in what form. The comprehensive publication by the World Health Organization (WHO) and the Food and Agricultural Organization of the United Nations (FAO), "Guidelines on Food Fortification with Micronutrients" assists countries in the design and implementation of appropriate food fortification programs and is particularly helpful for low- and middle-income countries.[1] The WHO/FAO publication provides guidance on the selection of food vehicles, and which micronutrients to add, in what chemical form, and in which quantities. More specific rice fortification guidelines are in development.

> "An analysis of which micronutrient deficiencies are likely to exist will help determine which micronutrients should be used to fortify rice"

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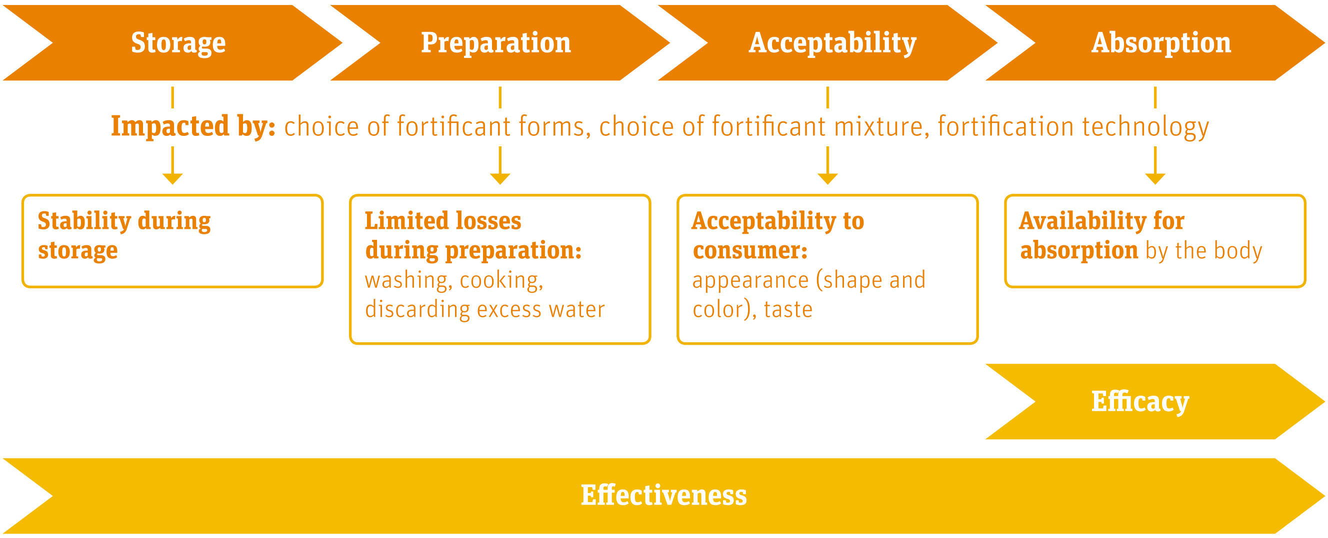
A father feeding his young child, Bolivia 2012

FIGURE 1: Factors that determine the efficacy and effectiveness of rice fortification



Requirements for rice fortification to be effective

For a rice fortification program to be effective, the following conditions need to be met:

- **a)** The micronutrients used to fortify the rice should remain stable during storage, i.e., losses over time are limited.
- **b)** The micronutrients should be retained after preparation (washing, cooking, discarding excess water).
- **c)** The fortified rice should be acceptable to the consumer in appearance (shape and color), taste and smell.
- **d)** The micronutrients remaining post-cooking should be available for absorption by the body (see **Figure 1**).

These requirements are affected by the fortificants' chemical forms and formulation, the fortification technology, and any possible interaction between micronutrients, or the rice matrix. Finally, the fortified rice needs to be consumed regularly and in the expected quantities by the desired population groups in order to make a good contribution to micronutrient intake.

Global evidence for rice fortification

The following is a review of two types of studies conducted on micronutrient fortification of rice that address the conditions illustrated in **Figure 1**. One type of study examines the *efficacy* of key micronutrients used in rice fortification. These carefully controlled studies assessed whether consumption of a given amount of rice, fortified with micronutrients in a specific concentration, using specific fortificant forms and fortification technology, resulted in the micronutrients being absorbed and utilized by the body. In *effectiveness* studies, people in specific population groups were provided with fortified rice under less controlled circumstances. The studies assessed whether these groups – who prepared and consumed the fortified rice in their homes – showed a reduction in the signs of micronutrient deficiencies or changes in micronutrient status. Under these studies, impact on the micronutrient status of participants was also dependent on storage, preparation, acceptance, and unsupervised consumption of the fortified rice.

Efficacy studies of fortified rice

Since early 2000, thirteen efficacy studies have been published that assessed the impact of fortified rice on micronutrient status.[2–14] All studies used fortified kernels that were produced using extrusion technology. Each study was conducted in a controlled environment, and aimed to compare impact on micronutrient status among individuals who received fortified rice, versus individuals who received non-fortified rice and/or micronutrients in supplement form. In nine of the studies, the rice was fortified only with iron, in one study only with vitamin A,[14] and in three studies a combination of micronutrients was used, i.e., iron, zinc and vitamin A in the studies by Pinkaew et al,[11,12] and iron, zinc, vitamins A, B_1, B_6 and B_{12} and folic acid in the study by Thankachan et al.[13] The studies were conducted in low- and middle-income countries, including the Philippines, India, Nepal, Thailand, Mexico and Brazil. Study populations included children aged 6–23 months, preschool and school-age children, women of reproductive age, and anemic individuals.

Iron results

All 12 efficacy studies on iron-fortified rice used ferric pyrophosphate (FePP) as the iron form. One study also included a group that received ferrous sulfate.[10] Although FePP is not the most bioavailable iron fortificant, it has so far been the only type of

TABLE 1: Studies on iron-fortified rice

Reference	Country	Study group	Dosage	Findings
Angeles-Agdeppa I, Capanzana MV, Barba CV et al[2]	Philippines	6–9 y old anemic children	10 mg/d (2 groups: FePP and ferrous sulfate)	Hb improved, anemia declined, no change of serum ferritin
Beinner MA, Velasquez-Meléndez G, Pessoa MC et al[3]	Brazil	6–24 mo old anemic children	23.4 mg/d	Hb improved, anemia declined, serum ferritin increased, iron status improved
Hotz C, Porcayo M, Onofre G et al[4]	Mexico	18–49 y old women (non-pregnant, non-lactating)	20 mg/d	Hb increase non-sign. (p=0.069), plasma ferritin, transferrin receptor, and iron stores improved
Nogueira Arcanjo FP, Santos PR, Leite J et al[5]	Brazil	10–23 mo old children	56.4 mg/meal, one meal/wk	Hb improved, anemia declined
Nogueira Arcanjo FP, Santos PR, Segall S[6]	Brazil	2–5 y old children	56.4 mg/meal, one meal/wk	Hb remained the same, whereas it declined in control group
Nogueira Arcanjo FP, Santos PR, Arcanjo C[7]	Brazil	10–23 mo old children	56.4 mg/meal, one meal/wk	Hb improved, anemia declined
Moretti D, Zimmermann MB, Muthayya S et al[8]	India	6–13 y old schoolchildren	13 mg/d	Body iron stores improved (all other Hb and iron status parameters, no change)
Radhika MS, Nair KM, Kumar RH et al[9]	India	5–11 y old schoolchildren	19 mg/d	Hb and anemia no change, serum ferritin increased, iron deficiency reduced
Zimmermann M, Muthayya S, Moretti D et al[10]	India	5–9 y old schoolchildren	10 mg/d	Hb no change, transferrin receptor no change, serum ferritin increased, iron deficiency declined
Pinkaew S, Winichagoon P, Hurrell RF et al[11]	Thailand	4–12 y old schoolchildren	12.3 mg/d	Hb and serum ferritin, no change, iron deficiency declined
Thankachan P, Rah JH, Thomas T et al[13]	India	6–12 y old schoolchildren	6.25 mg/d and 12.5 mg/d	Hb and iron status indicators, no change

iron identified that does not affect the color and taste of rice. Research has very recently been conducted that successfully increased the bioavailability of this type of iron.[14] The amount of fortified rice that was provided in the studies ranged from 50 g/week to 140 g/day and was often provided as one meal per day. The blending ratios of the fortified rice ranged from 0.5 to 2.5%, and the iron content of the fortified rice meal ranged from 6 to 56 mg. The studies did not report on the color of the fortified kernels or the acceptability of the fortified rice, but as feeding took place under controlled conditions, all participants were apparently willing to consume the rice. Eleven of the 12 studies with rice fortified with iron assessed impact on hemoglobin concentration or anemia. None of the studies found a negative impact, while five found an improvement. Six of the eight studies that assessed iron status found an improvement. In total, 10 of the 11 studies found a positive impact on either hemoglobin concentration or iron status, or on both (see **Table 1**). The authors of the one study that found no impact on hemoglobin concentration or iron status reported that they discovered post-study that the participants had actually received iron supplements until a few months before the study started.[13]

These results provide strong evidence that the fortification with iron was effective. The fact that a greater proportion of studies found an impact on iron status as compared to the proportion that found an impact on hemoglobin concentration may be due to homeostatic control (i.e., there is limited room for improvement of hemoglobin concentration among non-anemic individuals) and due to the fact that iron deficiency causes only approximately 50% of anemia. As other nutritional and non-nutritional causes also affect anemia, there are limits on the impact of iron on hemoglobin concentration.

When considering fortification of rice with iron at scale, cost and consumer acceptability are key. Blending ratio impacts cost. Color and taste, which depend on choice and level of iron fortificant, can affect consumer acceptance. These aspects were less important in the efficacy studies. With the current recommended fortificant form of micronized ferric pyrophosphate in order not to have a colored fortified kernel, the concentration of iron cannot exceed 7 g/kg. When fortified kernels are blended with normal rice at 1%, which is a commonly used ratio, the iron content of the fortified rice will be 7 mg/100 g. Most of the efficacy studies blended at a higher ratio, and some also had a higher concentration of iron in the fortified kernels. The high iron concentration in the fortified rice, and the fact that most studies provided all the iron in one meal per day, resulted in high iron content in comparison to that of

TABLE 2: Studies on vitamin A fortified rice

Reference	Country	Study group	Dosage	Findings
Pinkaew S, Wegmuller R, Wasantwisut E et al[12]	Thailand	8–12 y old children	3,000 µg RE/d	BL* serum retinol 1.21 µmol/L – total body retinol increased – serum retinol unchanged
Pinkaew S, Winichagoon P, Hurrel RF et al[11]	Thailand	4–12 y old children	2,500 µg RE/d	BL serum retinol 1.01 µmol/L – No significant increase
Thankachan P, Rah JH, Thomas T et al[13]	India	6–12 y old children	500 µg RE/d	BL serum retinol 2.1–2.6 µmol/L – No change
Haskell MJ, Pandey P, Graham JM et al[15]	Nepal	Night-blind pregnant women	850 µg RE/d	Serum retinol increased in all groups, most in liver & high-dose capsule groups

*BL: baseline

iron absorption inhibitors. This may have had a further positive impact on iron absorption in the studies.

Vitamin A results

Four studies included rice fortified with vitamin A, three of which were also fortified with other micronutrients. The one study that fortified rice only with vitamin A was conducted among night-blind pregnant women in Nepal and provided study groups with different sources and levels of vitamin A.[15] This study reported an improvement of vitamin A status in all groups, with the greatest improvement in the two groups that received vitamin A from either a high-dose capsule or liver. The other three studies were conducted among schoolchildren with an average baseline serum retinol concentration considered indicative of adequate, or close to adequate, vitamin A status[11–13] (see **Table 2**). Their serum retinol concentration did not increase further. However, the one study that also measured total body retinol reported an improvement.[12] This evidence shows that vitamin A can effectively be added to rice. However, it is important to consider whether rice is the most appropriate vehicle. For example, where cooking oil is already adequately fortified with vitamin A, it is not also necessary to fortify rice with vitamin A.

Results with other micronutrients

The impact of fortification of rice with zinc, folic acid, vitamins B_1 (thiamin) and B_{12} on micronutrient status has also been assessed. Thankachan et al[13] studied rice fortified with iron, zinc, vitamins A, B_1, B_6 and B_{12} and folic acid. In a study by Pinkaew et al,[11] impact on zinc status by rice fortified with iron, vitamin A and zinc was assessed. Thankachan et al found an improvement of vitamin B_{12} status and a decrease of homocysteine levels.[13] This indicated that both vitamin B_{12} and folic acid were well absorbed and utilized. They found no change of indicators of thiamin or zinc status. Thiamin status was already sufficient. The absence of impact of zinc fortification on serum zinc concentration, which has also been reported by other studies,[16] may be due to the fact that only a small fraction of the body's zinc pool appears in serum. This makes it insensitive to modest changes of status. The study by Pinkaew and colleagues reported a decline of zinc deficiency in both the intervention and the control groups. The improvement of serum zinc was greater in the fortified rice group compared with the unfortified rice group.[11]

Effectiveness studies – impact of rice fortification under programmatic circumstances

Four studies analyzed the effectiveness of rice fortification under less controlled, more programmatic, circumstances.[17–20] The first study, conducted in the Philippines in 1947–49, used coated rice fortified with thiamin, niacin and iron. Results showed a substantial reduction of beriberi, a well-known consequence of thiamin deficiency, as well as a lower incidence of infant deaths in the areas that received fortified rice.[20] No biochemical indicators of micronutrient status were assessed at that time. A second effectiveness study in the Philippines in 2008 provided rice fortified with iron at approximately 3–4 mg/100 g. This study found higher hemoglobin concentrations among children after the program than before, and a decline in anemia prevalence. No changes were found among mothers.[18] A study conducted in Thailand between 1971 and 1975 distributed fortified rice among different age groups of children. No significant differences were found in anthropometry, hemoglobin and hematocrit between children of the villages that received the fortified rice and those that received non-fortified rice. According to the authors, caloric insufficiency was widespread and may have affected the results.[19] More recently, after observing declines in neural tube defects (NTD) after the introduction of flour fortification with folic acid, Costa Rica also began fortifying rice and milk with folic acid. Studies conducted in 2011 demonstrated further NTD declines.[17]

Recommended micronutrients for rice fortification

The above reviewed evidence from efficacy and effectiveness studies supports the fortification of rice with iron, vitamin A, folic acid, vitamin B_{12} and thiamin. Zinc is also recommended, although one study found an impact on zinc status while the other one did not. These mixed findings are consistent with findings from studies on zinc fortification of other foods and may partly be due to the fact that zinc status is difficult to assess accurately.[16] For niacin and vitamin B_6, data of impact on micronutrient status have not yet been collected, but adding these is recommended as well, because polished rice is a poor source of these essential micronutrients,[21] bioavailable forms of these nutrients exist, and adding them to rice together with the other micronutrients does not markedly increase the costs of fortified rice.

> "The above evidence supports the fortification of rice with iron, vitamin A, folic acid, vitamin B_{12} and thiamin, and the addition of zinc, niacin and vitamin B_6 is also recommended"

Research and development

Research is under way to identify more bioavailable forms of iron, which is important for safeguarding the impact on iron status under normal circumstances (see iron section above) while maintaining good consumer acceptability. Research is ongoing to compare micronutrient retention and absorption of fortified rice produced with rinse-resistant coating versus extrusion technology.

What to assess when introducing rice fortification at scale

Figure 1 shows essential components for effective rice fortification. First is the choice of the appropriate fortification technology, and identification of required micronutrients. The selected fortificants must be in efficacious forms and required amounts, and stable. Required evidence and information for this step is presented in this article, in the article on technology by Montgomery et al (see p. 159), and in the paper on standards by de Pee and Fabrizio (see p. 165). After technology and types of levels of fortificants have been chosen, it is very important to assess production feasibility (initially, just for blending, later also fortified kernel production), and consumer acceptability. Then the following should be put in place:

- **Quality assurance, quality control and monitoring**
  Manufacturers should conduct their own quality assurance and quality control. Separately, independent monitoring should determine whether the rice is fortified as expected, i.e., the fortified kernels have the required composition and are blended at the required ratio and staying within a given range of variation. In addition, stability testing needs to be conducted under prevailing storage, preparation and cooking conditions to assure content remains adequate.
- **Monitoring of coverage, acceptability and consumption levels**
  These aspects need to be monitored, and adjusted where necessary. The contribution of fortified rice to micronutrient intake depends on whether consumers obtain, accept and consume it in required quantities.
- **Monitoring of micronutrient intake, morbidity and micronutrient status**
  Since rice fortification is one component of a broader strategy to address micronutrient deficiencies, monitoring should assess whether the combination of strategies is improving the health and nutritional status of different target groups in the population and/or whether additional measures may be required. Monitoring should be conducted over time, including assessment before and after implementation of the program has started at scale.

> "Countries considering rice fortification do not need to conduct additional efficacy studies"

Conclusion

Multiple studies have established that with the appropriate levels of micronutrients and fortificant forms, and with effective technology, fortified rice is an effective intervention to improve micronutrient status. Countries considering rice fortification as an intervention to address micronutrient deficiencies do not need to conduct additional efficacy studies. Rather, countries should apply their resources to assess their own public health needs for micronutrient fortification and ensure close monitoring of implementation. The recommended micronutrients for rice fortification are iron, zinc, folic acid, niacin and vitamins A, B_1 (thiamin), B_6 and B_{12}, although if vitamin A is added to vegetable oil, it may not need to be added to rice. These recommendations are based on efficacy data, and the public health significance of the deficiencies of these micronutrients. In addition consideration is given to the feasibility of adding specific fortificants while maintaining consumer acceptability and stability during storage. Countries should therefore focus on appropriate fortification (i.e., fortified kernels and their blending), storage and distribution, and monitoring acceptance and consumption (adequate quantities and by different subgroups).

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Rice Fortification: Evidence, Status, and Lessons Learned in Grain Fortification

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Key Messages

- Like wheat and maize flour fortification, fortifying rice is a public health opportunity to prevent micronutrient deficiencies and serious birth defects of the brain and spine. Scientific literature shows that rice fortification can improve iron status in targeted populations – other nutrients are not as well studied.[1]
- At a national scale, rice fortification is mandatory in six countries, and several subnational efforts indicate that interest in, and the practice of, rice fortification is growing. In comparison, 85 countries globally have mandatory wheat flour fortification legislation.[2]
- Fortification of wheat flour with essential vitamins and minerals has been practiced for over half a century; lessons learned in the implementation of wheat flour fortification programs globally can be applied to rice fortification in Latin America and the Caribbean.

Rice fortification technologies

Coated: Rice kernels are coated with a fortificant mix plus ingredients such as waxes and gums. The micronutrients are sprayed onto the surface of the rice grains. The coated rice kernels are blended with non-fortified rice in a ratio between 1:50 and 1:200.

Extruded: Rice-shaped reconstituted kernels are produced by passing rice flour dough, containing a fortificant mix, through an extruder. The extruded kernels are then blended into non-fortified rice in a ratio between 1:50 and 1:200.

Public health evidence for rice fortification: A review of efficacy and effectiveness studies

The Food Fortification Initiative (FFI) conducted a review of rice fortification literature indexed in PubMed and found 16 efficacy trials and five effectiveness studies;[3] this study and an update are available on the FFI website. Studies used either coated or extruded kernels. Eligible English- and Spanish-language studies provided health indicator comparisons of groups eating fortified rice and those eating non-fortified rice.[4]

Efficacy studies

The results of the review are summarized in **Table 1** and **Table 2**. Sixty-four percent (7/11) of studies measuring ferritin concentrations found a significant increase after the intervention group consumed rice fortified with iron. By contrast, only 30% (5/15) of studies measuring hemoglobin found a significant increase in hemoglobin levels. Anemia has multiple etiologies, only one of which is related to iron deficiency.[5] In populations with confounding factors such as parasitic infections (e.g., intestinal worms and malaria), high proportions of inherited blood disorders, and other multiple micronutrient deficiencies, iron indicators are a more direct measure of the impact of rice fortified with iron.[6]

Table 2 presents the results for efficacy studies that evaluated other nutrients added to rice. After iron, vitamin A is the next best-studied nutrient in rice fortification, with five studies

Types of research[a]

Efficacy: The outcomes of a specific intervention *under ideal conditions* ... Ideally, *a randomized controlled trial.*

Effectiveness: The outcomes of a specific intervention, *when deployed in the field in the usual circumstances.*

[a]Porta M. A dictionary of epidemiology. Oxford: Oxford University Press, 2008.

evaluating plasma retinol concentrations. However, the results for vitamin A are equivocal, possibly because vitamin A is a homeostatically controlled nutrient in the body,[7] and identifying significant changes is most likely when the targeted individuals have low vitamin A reserves. Two or fewer studies assessed the rest of the nutrients.

Effectiveness studies

Five studies, in Costa Rica, India, Thailand, and the Philippines, assessed rice fortification in the context of a large effectiveness trial (**Table 3**). The trials studied different populations and different outcomes, and three of the five included more than one nutrient in the rice. Four of the five studies reported improved outcomes (decrease in neural tube defects (n=1/1), increase in hemoglobin (n=2/4), decrease in anemia (n=2/3), decrease in beriberi incidence (n=1/1), decrease in infant beriberi deaths (n=1/1), although statistics were not always reported. The body of effectiveness data is relatively small and not easy to compare, but it indicates beneficial outcomes for rice fortification.

Key takeaways

In multiple studies, iron indicators improved in participants consuming fortified rice. Studies of the health impact of rice fortification largely focus on the impact on iron indicators, anemia prevalence, or hemoglobin concentrations. A limited number of effectiveness or efficacy studies assess other nutrients. Using indicators specific to the nutrients added through fortification is key when evaluating the health impact of rice fortification.

> "In multiple studies, iron indicators improved in participants consuming fortified rice"

Current status of global rice fortification programs and projects

Fortification activities, programs, or projects can be classified as mandatory, voluntary, or delivered via social safety nets.[8] One, two, or all three types of rice fortification can occur in a single country. For example, a country can have mandatory legislation for rice fortification for iron, folic acid, and zinc, and it could also have standards that allow rice producers to voluntarily include additional nutrients. Social safety nets are typically welfare programs targeted towards vulnerable populations. Examples include school feeding programs, food distribution programs, workplace benefit programs, or emergency aid rations.

Mandatory fortification

FFI monitors the global status of mandatory legislation for cereal grain fortification. In 2014, realizing that the bulk of rice

TABLE 1: Summary of rice fortification efficacy studies assessing iron indicators[a,b]

Outcome assessed (unit)	Number of studies that found significant improvement in this outcome	Total number of studies that investigated this outcome
Hemoglobin (g/L)	5	15
Anemia (%)	5	9
Iron status		
Ferritin (µmol/L)	7	11
Iron deficiency (%)	6	7
Transferrin receptor (mg/L)	3	5
Iron-deficiency anemia (%)	0	2
Iron body stores (mg/kg)	2	3
Zinc protoporphyrin (µmol/mol heme)	1	2
Total iron binding capacity (µg/dL)	1	1

[a] n=16 efficacy studies

[b] Food Fortification Initiative (FFI). Rice fortification's impact on nutrition. Atlanta: FFI, 2014. Updated 2016.

TABLE 2: Summary of rice fortification efficacy studies assessing other nutrient indicators [a,b]

Outcome assessed (unit)	Number of studies that found significant improvement in this outcome	Total number of studies that investigated this outcome
Plasma retinol (μmol/L)	2	5
Vitamin A deficiency (%)	1	2
Total body retinol reserves (μmol)	1	1
Serum zinc (μmol/L)	2	2
Zinc deficiency (%)	0	1
Folate (ng/mL)	1	1
Homocysteine (μmol/L)	1	1
Plasma B_{12} (pmol/L)	1	1
Thiamin (nmol/L)	0	1

[a] n=16 efficacy studies

[b] Food Fortification Initiative (FFI). Rice fortification's impact on nutrition. Atlanta: FFI, 2014. Updated 2016.

fortification activities were outside of mandatory legislation, with help from partners, FFI began collecting and disseminating information on the status of voluntary and social safety net programs as well. This information is gathered through quarterly phone calls with partners who work in rice fortification. **Figure 1** depicts current mandatory, voluntary, and social safety net programs in rice fortification.[9] As of September 2016, six countries have mandatory legislation for rice fortification: Costa Rica, Nicaragua, Panama, Papua New Guinea, the Philippines, and the USA.[10] Legislation does not necessarily mean successful implementation; lack of feasibility in the private sector and lack of strong regulatory enforcement can hinder even the most well-intentioned fortification programs. Of those six countries, only Costa Rica, Papua New Guinea (PNG), and the USA fortify over 70% of the country's industrially milled rice.[11] In the Philippines, a rice milling industry dominated by thousands of small rice mills scattered across an island archipelago challenges implementation,[12] whereas in Nicaragua lack of regulatory enforcement is a barrier.[13] It is not clear what barriers exist in Panama. **Table 4** shows the nutrients and standards required in each country.

After passing a mandatory law for rice fortification, regulatory monitoring is needed to ensure that the legislation is implemented by private industry. For the past two years, FFI has been asking regulatory authorities in these countries about rice fortification monitoring activities.[14] The activities listed in **Table 5** are important actions that countries can take to ensure that, when implemented, their fortification programs have oversight, the necessary guidance for their regulatory agencies to enforce, and transparency.

A mother with her two children, Guatemala 2012

Voluntary rice fortification

Fortified rice is commercially available in four additional countries through companies that voluntarily market fortified rice: Brazil, Colombia, Peru, and Myanmar (**Figure 1**). In these countries, companies typically choose the types of nutrients and levels to add, as no countries currently have voluntary standards for rice fortification. Voluntary standards are useful tools to guide food producers and also ensure that when com-

TABLE 3: Rice fortification effectiveness studies[a]

Study and country	Study population (sample size)	Nutrients in fortified rice	Result
Arguello et al 2011[b] Costa Rica	Births in country (n=65,000–75,000 per year)	Folic acid*, vitamin B_{12}, thiamin, zinc, vitamin E, selenium	Statistically significant decrease in NTDs** from pre to post rice and milk fortification*
Angeles-Agdeppa et al 2011[c] Philippines	Mothers (n=392) and their children 6–9 years (n=424)	Iron	Statistically significant improvement in hemoglobin and anemia for children, but not their mothers
Gershoff et al 1977[d] Thailand	Children 1.5–9 years (n=2,250)	Thiamin, riboflavin, retinol, iron, lysine, threonine	No statistics reported. Authors stated no differences in hemoglobin or morbidity between high (67% of time) and low (10% of time) consumers
Paithankar et al 2015[e] India	Children 6–15 years (n=945)	Iron	Statistically significant increase in hemoglobin and reduction in anemia prevalence for fortification district compared with control district
Salcedo et al 1950[f] Philippines	Infants, children >2–15 years old, mothers, pregnant mothers, and other adults (n=11,492)	Thiamin, niacin, iron	No statistics reported. Beriberi incidence and infant beriberi deaths decreased in fortification areas. In the non-fortification areas, these increased.

[a] n=5 effectiveness studies

[b] Arguello M, Solis L. Impacto de la fortificación de alimentos con ácido fólico en los defectos del tubo neural en Costa Rica. Rev Panam Salud Publica 2011;30(1):1–6.

[c] Angeles-Agdeppa I, Saises M, Capanzana M. Pilot-scale commercialization of iron-fortified rice: effects on anemia status. Food Nutr Bull 2011;32:3–12.

[d] Gershoff SN, McGandy RB, Suttapreyasri D. Nutrition studies in Thailand. II. Effects of fortification of rice with lysine, threonine, vitamin A, and iron on preschool children. Am J Clin Nutr 1977;30:1185–95.

[e] Paithankar P, Yunus S, Tiwari D. Mid-day school meals as social safety nets: an evaluation of the impact of iron fortification of Mid-Day Meals on the prevalence of anemia among children in Odisha, India (abstract). Internet: http://paa2015.princeton.edu/sessions/P7#72 (accessed 12 February 2017).

[f] Salcedo J Jr, Bamba MD, Carrasco EO et al. Artificial enrichment of white rice as a solution to endemic beriberi; report of field trials in Bataan, Philippines. J Nutr 1950;42:501-23.

* Wheat flour, maize flour, and milk are also fortified with folic acid

** NTD: neural tube defect

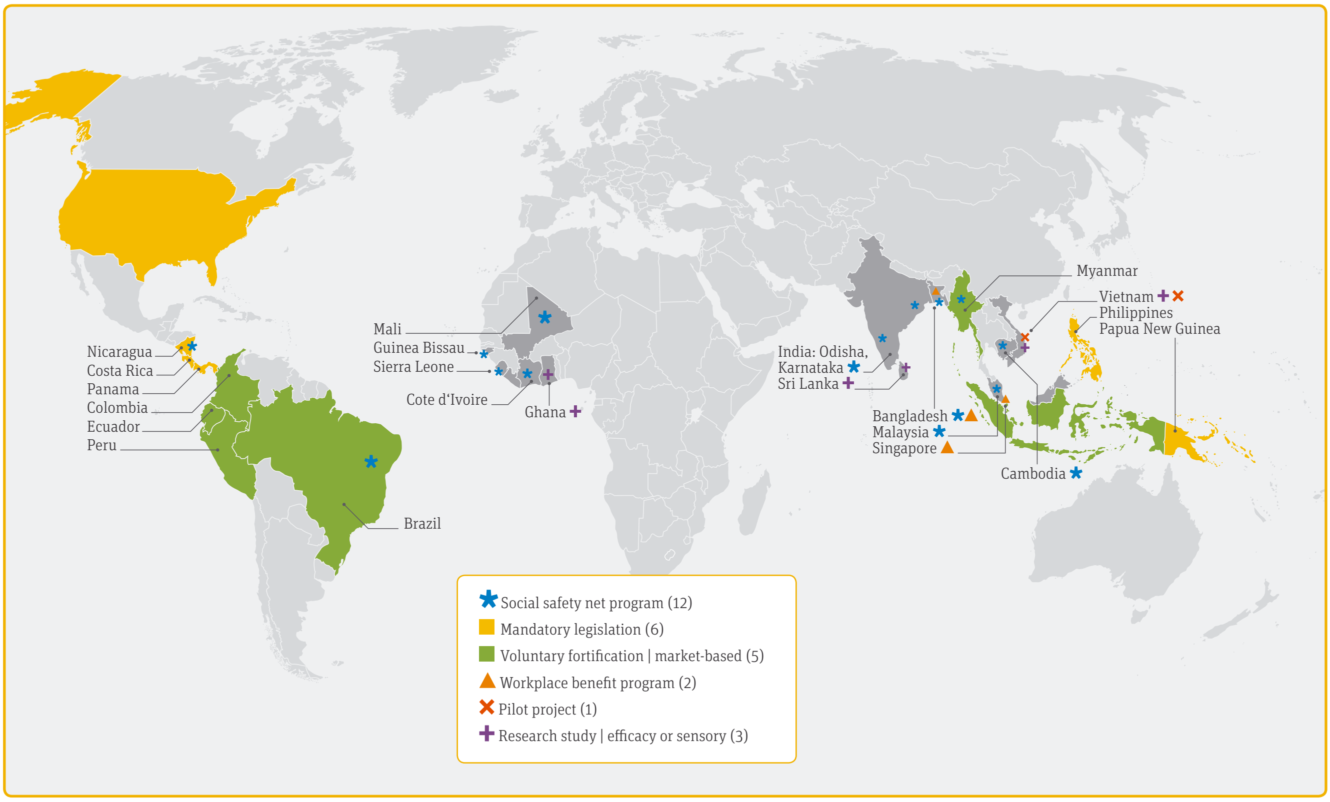
panies fortify, they do so at levels that are safe and intended for a public health benefit.

Since voluntary rice fortification is a choice made by an individual food producer or supplier, it can be difficult to achieve high coverage of fortified rice unless a monopoly exists or producers jointly agree to fortify. In all but one country, Colombia, the availability of fortified rice is estimated at less than 2% of the total rice industrially milled in the country.[15] Colombia's experience with voluntary rice fortification shows that moderate coverage of fortified rice can be achieved.[16] Even if coverage is high, however, the use of an effective technology is also essential to ensure that fortification contributes to public health. An issue in voluntary fortification is that there is more discretion about how to fortify and effective methods might not always be chosen.

Social safety nets

Social safety nets typically target those considered at need; their sustainability is reliant on the funding agency – usually a non-governmental organization, government agency, or in some cases also a private employer. Fortifying the rice already distributed (i.e. not a cash-transfer system) in a school feeding program, emergency ration, or food basket can be a way to improve nutrition at a relatively small additional cost to the overall program. Distributing fortified rice through social safety nets is most efficiently done through a centralized delivery system – for example, through a warehousing center that can distribute fortified rice in a food basket, a centralized kitchen that can bulk-cook fortified rice and distribute it to schools, or a modern rice mill that can produce large quantities of fortified rice to bid for procurement contracts.

FIGURE 1: Global status of rice fortification programs [a]



[a] Does not include research studies involving fortified rice, but includes pilot studies that are intended to demonstrate feasibility of rice fortification (rather than efficacy).

Currently, several countries feature rice fortification in social safety nets – in Bangladesh the government's Vulnerable Group Feeding/Development programs provide fortified rice to low-income populations,[17] and a garment factory staffed primarily with female employees began providing fortified rice in lunches in December 2015.[18] The World Food Programme distributes fortified rice through school feeding programs in Bangladesh, Odisha State in India, and Cambodia (**Figure 1**). In Singapore, construction companies are working with a social enterprise, *45Rice* (a play on the phonetic similarities between the number "45" and "fortified"), to source fortified rice for the caterers that feed their migrant workers.[19]

"Mandatory fortification can reach high population coverage if implemented and enforced by regulatory agencies that are supported by political commitment and policies"

Key takeaways

Mandatory fortification can reach high population coverage if implemented and enforced by regulatory agencies that are supported by political commitment and policies.[20] Outside of special exceptions (such as monopolies or oligopolies), sustained, high coverage of fortified rice is difficult to achieve in voluntary fortification, but voluntary standards can at least help ensure quality fortification. Social safety net programs offer the opportunity to target populations who are most at need of nutritional interventions, but they require the commitment of the implementation agency for sustained delivery.

Lessons learned from wheat flour fortification

Fortification is most sustainable in a modern milling industry

Perhaps one of the greatest lessons learned from wheat flour fortification is the importance of a modern milling industry.[21,22] Fortification relies on both the private sector to produce high-quality fortified foods under safe and hygienic conditions and the government to ensure a fair business environment by enforcing national regulations among all millers.[23] When milling of wheat, maize, or rice occurs most frequently in the home or in villages, fortification is technically feasible but very

TABLE 4: Fortification levels (mg/kg) of vitamins and minerals in mandatory rice fortification countries[a]

Fortification Levels (mg/kg)

	Vitamins					Minerals			
Country	**Thiamin (B_1)**	**Niacin (B_3)**	**Pyridoxine (B_3)**	**Folic Acid (B_9)**	**B_{12}**	**Iron**	**Type of Iron**	**Selenium**	**Zinc**
Costa Rica	5.3	35	–	1.8	0.01	–	–	0.105	7.5
Nicaragua	5	40	4	1	0.01	24	Ferric pyrophosphate	–	25
Panama	5	40	4	1	0.01	24	Ferric pyrophosphate	–	25
Papua New Guinea	5	60	–	–	–	30	Not specified	–	–
Philippines	–	–	–	–	–	60–90	Ferrous sulfate	–	–
USA	4.4–8.8	35.2–70.4	–	1.54–3.08	–	28.6–57.2	Not specified	–	–
No. countries	5	5	2	4	3	5	3	1	3

[a] Food Fortification Initiative Database, 2016. Unpublished.

difficult to sustain financially, monitor for quality, and produce consistently.[24] Small-scale and home producers usually do not have the available capital to purchase premix or invest in fortification equipment. Regular miller training at the village level to ensure consistency is both resource- and time-consuming for millers and government agencies. And finally, government agencies already stretched to regulate food safety are simply unable to monitor milling when it occurs at thousands or tens of thousands of mills, as is the case with rice milling in countries like Sri Lanka,[25] Philippines,[26] and Vietnam.[27]

Fortification is most easily sustained when it capitalizes on a centralized milling industry. Future efforts in rice fortification should include milling industry analyses[28] as part of a fortification feasibility assessment.

Mandatory fortification is more likely to achieve public health impact than voluntary

Consumers are extremely sensitive to grain prices because wheat flour, maize flour, and rice are everyday staple foods eaten in large amounts. With wheat flour and oil, consumers who are more concerned with pricing than branding are unable to afford more expensive voluntarily fortified products.[29,30] Customers have limited and varying access to voluntarily fortified food, with a correspondingly unstable health impact.[20] Both of these problems have been demonstrated with voluntarily fortified food in Ireland, where products with folic acid have decreased in availability,[31] and researchers have found recent increases in the rate of neural tube defects.

Research in Australia demonstrated that mandatory fortification was more effective than voluntary for improving blood folate levels,[33] and also preventing neural tube defects.[34] Australia allowed food processors to voluntarily add folic acid to wheat flour for several years before mandating fortification of bread flour with folic acid in 2009. A clinic's analysis of blood folate concentrations during the voluntary and mandatory periods showed a marked increase in blood folate concentrations only after mandatory fortification came into place.[33] Similarly, the birth prevalence of neural tube defects remained relatively stagnant in Australia during the voluntary fortification period, with decreases only occurring after mandatory fortification had been implemented.[34]

Following WHO recommendations for fortification appears to be related to program effectiveness

In 2009, the World Health Organization (WHO) released global recommendations for wheat flour and maize flour fortification.[35] Fortification should provide enough of a nutrient to produce a public health benefit, but not so much as to be unsafe. These evidence-informed standards help countries set beneficial and safe standards.[36]

In 2015, FFI and partners conducted a review of reports from 13 countries which had conducted pre- and post-fortification evaluations.[37] Only one third of studies observed a decrease in anemia after fortification. We looked at whether countries followed two iron-related WHO recommendations: they used a recommended iron compound and they used at least the recommended level of iron. In programs that followed both WHO recommendations, two age subgroups showed a decrease in anemia prevalence. In programs that did not follow both WHO recommendations, 10 of 12 age subgroups did not experience a decline in anemia prevalence. These and results from another study[38] suggest that following WHO recommendations for flour fortification can lead to declines in anemia, while not following WHO recommendations can lead to null results. Experience from countries that mandatorily fortify flour with folic acid also points to the importance of following WHO recommendations. We completed a review of eleven countries' reductions in neural tube defects following fortification of wheat flour (alone, or in combination with maize flour) with folic acid.[39] The amount of folic acid added to flour in these

TABLE 5: Rice fortification monitoring activities reported in 2015 among countries with mandatory rice fortification [a,b,c]

Monitoring item	CR	Nica	Pan	PNG	Phil
Is there a national committee that oversees the rice fortification program?	Yes	Yes	Yes	No	Yes
Are rules and operating procedures for external monitoring of rice fortification at mill level by national authorities stipulated in a document?	Yes	Yes	–	No	No
Are rules and operating procedures for commercial monitoring of rice fortification at retail level by national authorities stipulated in a document?	No	No	–	No	No
If import rice, are rules and operating procedures for verification of rice fortification at import level by national authorities stipulated in a document?	Yes	Yes	NA	No	No
In the past five years, has a national report on the status of rice fortification monitoring and compliance been compiled?	Yes	No	–	No	No

[a] CR: Costa Rica; Nica: Nicaragua; Pan: Panama; PNG: Papua New Guinea; Phil: Philippines; NA: not applicable; –: No answer; No data for USA

[b] Food Fortification Initiative Database, 2016. Unpublished.

[c] Food Fortification Initiative (FFI). 2015 year in review. Atlanta: FFI, 2016.

What information should a milling industry analysis include?

An analysis can provide a high-level description of the milling industry: how many mills are in the country, average milling capacity, and geographic clusters. An in-depth look at individual mills in the country can inform as to which mills already have fortification capacity (e.g., equipment, human resources, quality assurance practices) and which may require support to implement.

countries (1.2–2.2 mg/kg) is within the range recommended by WHO (1.0–5.0 mg/kg).

Rice fortification recommendations are forthcoming from WHO.[40] For rice fortification programs with safe and optimal effects on nutrition status, countries should fortify with adequate levels of the recommended iron compounds and other micronutrients.[41]

Conclusions

Scientific literature shows that rice fortification can produce a public health impact, particularly on iron status, as that is the most-studied nutrient. Research for other nutrients is limited yet encouraging. The evidence for other nutrients, particularly folic acid, in wheat flour could be translated to rice. At the same time, rice fortification activities have also largely moved past efficacy and effectiveness studies, onto national programs, voluntarily fortified products in select marketplaces, pilot implementation projects, and social safety net programs targeted at schoolchildren and other vulnerable populations.

The past lessons learned in wheat flour fortification can save valuable resources and improve efficiency in planning for rice fortification programs or evaluating existing programs. These lessons point to ensuring sustainability by pursuing fortification in a modernized milling industry; introducing mandatory fortification with strong regulatory enforcement for greater population coverage and impact; and setting standards in line with WHO recommendations to ensure safe and effective fortification. Rice fortification may be a relatively new public health intervention, but utilizing the past successes of fortifying wheat flour is a win-win for all.

"Rice fortification may be a relatively new public health intervention, but utilizing the past successes of fortifying wheat flour is a win-win for all"

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Technology for Rice Fortification

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Key Messages

- Rice fortification using either extrusion or coating technologies is a two-step process. The first involves the production of fortified kernels; the second, the blending of fortified kernels with non-fortified rice.
- Extrusion and rinse-resistant coating are the best available technologies to produce fortified kernels that remain stable under different storage conditions, preparation methods, and cooking techniques, and that are acceptable to consumers.
- Recommended vitamins and minerals to fortify rice include the micronutrients removed during processing, in addition to micronutrients needed to fill the target population's nutrient gaps. Fortification with multiple micronutrients is recommended, as micronutrient deficiencies often coexist.
- The choice of fortificant used to fortify rice depends on its bioavailability and stability, its impact on consumer acceptability, and the type of technology used.

Rice is the world's second most commonly consumed cereal grain. In recent years, rice fortification technology has evolved. As a result, rice fortification at scale is gaining momentum as a feasible and cost-effective strategy to address micronutrient deficiencies. To date, about 15 countries have introduced rice fortification on either a mandatory or a voluntary basis, embedded in social safety nets, or at limited scale through trials. This article provides an overview of technological challenges for rice fortification and explores rice fortification technologies available to produce fortified rice. It also discusses the use of potential fortificants (vitamins and minerals).

> "As for food fortification in general, rice should be fortified with micronutrient forms that are available for absorption by the body, and that remain stable"

Technological challenges for fortifying rice

As for food fortification in general, rice should be fortified with fortificants that are available for absorption by the body, and that remain stable during processing, storage, transport, preparation, and cooking methods and practices including discarding excess water.[1] Rice is consumed as a whole kernel, which complicates the fortification process and requires specialized technology. In contrast to flour fortification, where the premix and flour are both in powder form and can be easily blended, this is not an option with rice.

The micronutrients in the fortificant mix should not interact with each other and/or with the rice matrix, as this may influence color, taste and stability, thus lowering consumer acceptability. The fortificants must remain stable during different means of preparation such as washing before cooking, soaking, cooking in different amounts of water, and for varying amounts of time.[2,3]

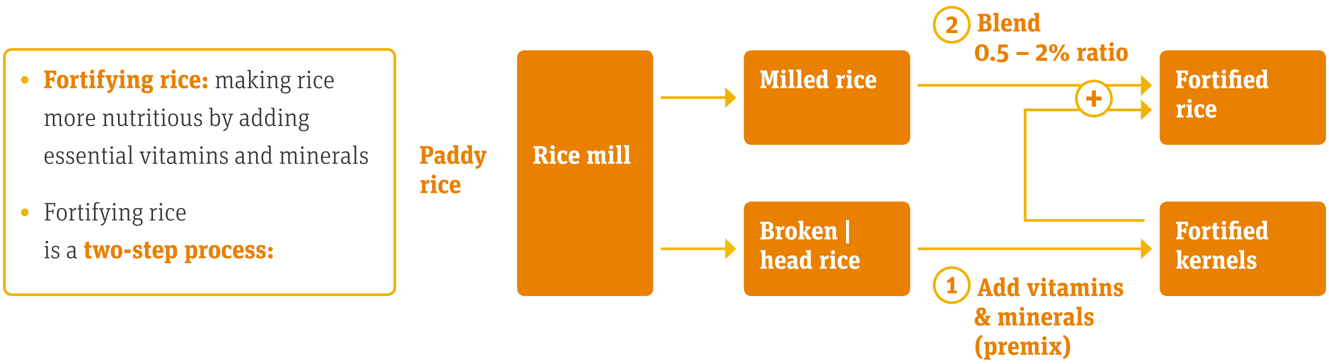
Appropriate quality assurance and quality control, as well as monitoring, are needed throughout the rice fortification process to ensure that standards are met and that the fortified rice effectively improves the nutritional health of the consumer.

Overview of available technologies for rice fortification

Dusting

Dusting is a fortification technology that adds micronutrients onto the surface of the rice grains. Dusting relies on electrostatic force to bind the fortificant in a dry powder form to the surface of the milled rice grains. This technology provides limited nutrient protection when rice is washed, soaked or cooked in excess water, which is then discarded. In the United States, dusting is acceptable since rice is not washed prior to cooking, nor cooked

FIGURE 1: Two-step process of rice fortification through coating or extrusion technology



in excess water. All packaged fortified rice sold in the United States includes a label advising against washing or cooking in excess water.

Coating and extrusion

As illustrated in **Figure 1**, fortifed rice is produced using a two-step process. First, coating or extrusion technology is used to produce fortified kernels. Second, the fortified kernels are blended with non-fortified rice at a ratio of 0.5% to 2% to result in fortified rice.

Option 1: Coating technology for production of fortified kernels

Coated fortified kernels are produced by coating rice grains, typically head rice, with a liquid fortificant mix. Additional ingredients, such as waxes and gums, are used to 'fix' the micronutrient layer or layers on the rice grain. Whole or head rice is evenly spray coated with micronutrients and other ingredients to preserve the coating. This is usually done in large rotational drum or pan coating machines. The coated kernels are then dried to yield fortified kernels. This technology concentrates the micronutrients on the surface of the rice grains. When cooked, the coating dissolves, spreading the micronutrients throughout the cooked rice. Where rice is washed or soaked, coated fortified kernels must be rinse-resistant so as to ensure micronutrient retention.

Option 2: Extrusion technology for production of fortified kernels

Extruded fortified kernels are formed by combining water and a fortificant mix with rice flour which is usually made from grinding lower value and non-contaminated broken rice, to form a dough (**Figure 2**). The dough is passed through an extruder, producing a fortified kernel visually similar to a non-fortified rice grain. Micronutrients are equally distributed inside the fortified kernel, with only a few particles left on the surface. This reduces the exposure to the environment and hence micronutrient degradation. The extruded fortified kernels are dried, reducing the water content to 14% or less, thus increasing stability during storage.

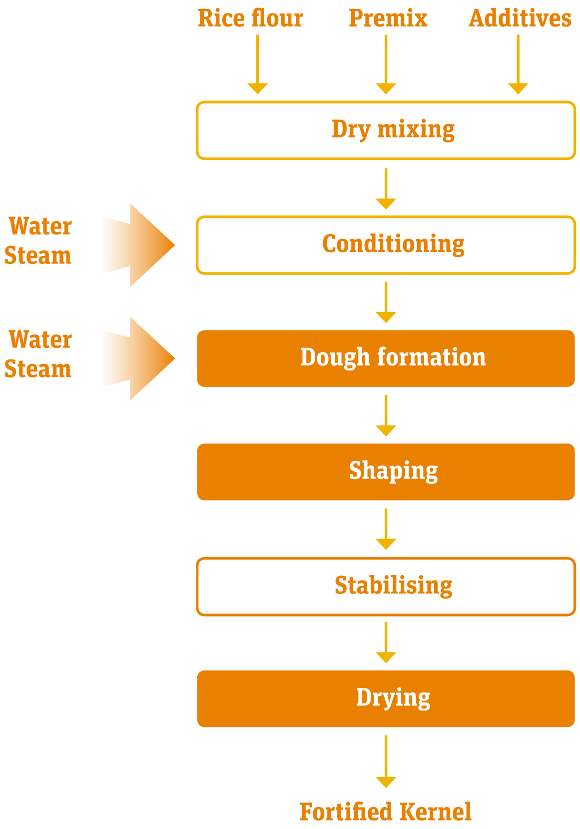
The amount of starch that is gelatinized in the fortified kernel influences color, texture and stability during soaking and cooking. This is affected by the temperature and the amount of water used during extrusion. In Cold extrusion (30°C–50°C), a pasta press is used to "shape" the dough and form opaque fortified kernels. This requires binders to be added or a subsequent boiling step to produce a cohesive product. Warm extrusion (60°C–80°C) also uses a pasta press, but adds a preconditioner with steam, or is equipped with a steam-injection device to produce fortified kernels that appear more translucent and more closely resemble non-fortified rice. An emulsifier can be used, but no additional additives are required. Hot extrusion (80°C–110°C) is more energy-intensive and, although not a requirement, ideally uses more sophisticated equipment. It can include a preconditioner, and can rely on a double screw extruder to produce the fortified kernels. An emulsifier (monoglyceride) can be added to maintain stability during storage of the fortified kernels. The resulting fortified kernels closely resemble different types of rice, with different degrees of translucency and texture.[2]

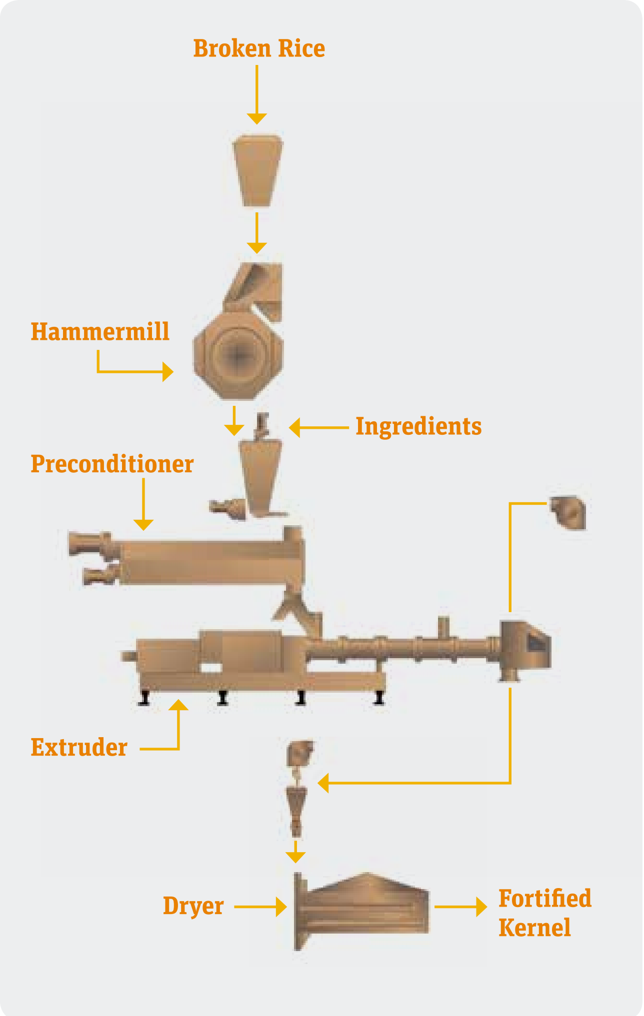
Fortified kernels made by either warm or hot extrusion are similar to non-fortified rice in their uptake of water during cooking, cooking time, and firmness. Kernels made by cold extrusion have a softer texture. In practice, most fortified kernel production with cold extrusion utilizes additional heat to improve the firmness and appearance, and can therefore be categorized as warm extrusion (see **Figure 3** for the appearance of fortified kernels using extrusion at different temperatures).

Step 2: Blending of fortified kernels and non-fortified rice

The coated or extruded fortified kernels are blended with non-fortified rice through a continuous or batch mixing process

FIGURE 2: Basic extrusion steps





(**Figure 4**). The blending ratio, typically between 0.5% and 2%, depends on the nutrient content of the fortified kernels and the desired level of fortification. Quality assurance and quality control are needed to ensure uniform blending at the correct ratio.

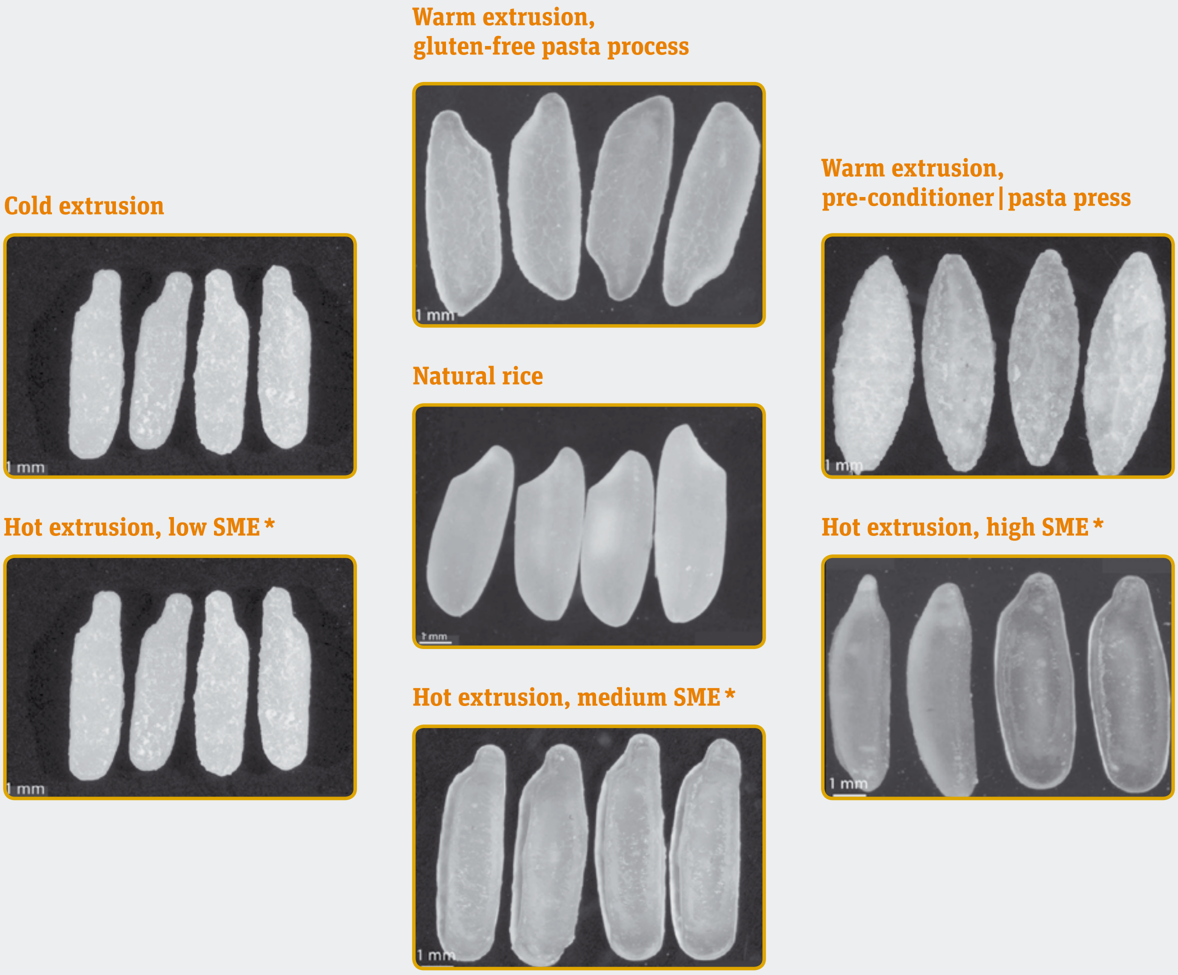
Other approaches to increase micronutrient intake through rice include parboiling, soaking, biofortification and communication for behavior change to increase consumption of brown rice.

Parboiling is not a fortification technology. No micronutrients are added to the rice; rather, parboiling causes the existing nutrients in the outer layers to be transferred and retained in the starchy endosperm of the rice grain. Consequently, parboiling enhances the intrinsic nutrient value of rice. The level of niacin, vitamins B_1 (thiamin) and B_6 (pyridoxine) is around three times as high in parboiled rice as it is in regular milled rice. For niacin and pyridoxine, the level in parboiled rice is similar to brown rice. However, parboiling does not increase the level of minerals, such as iron and zinc, nor is it a source of vitamin A or vitamin B_{12}. Overall, parboiled rice or brown rice is more nutritious than milled white rice, but only covers a limited part of the suggested micronutrients to add to fortified rice. Parboiled rice can be fortified.

For additional information on biofortification, and on consumption of brown rice, please refer to the contribution by Pachón et al (p. 188). Soaking is not discussed in this supplement, as research into this subject is still in initial stages.

"Micronutrients recommended for rice fortification are those which are removed during processing, in addition to those which address a target population's nutrient gaps"

FIGURE 3: Visual appearance of natural rice grains and extruded rice kernels produced with cold, warm and hot extrusion



* Specific Mechanical Energy (SME) is a measure of the mechanical energy required to push material through an extruder.

Overview of commonly used fortificants

Micronutrients recommended for rice fortification are those that address a target population's nutrient gap in addition to those removed during processing. Fortification with multiple micronutrients is recommended, as micronutrient deficiencies often coexist in low- and middle-income countries. The selection of fortificants depends not only on their bioavailability, stability, and sensory acceptability, but also on the fortification technology utilized. For additional information on fortificants, please refer to the contribution by de Pee and Fabrizio (p. 165).

To be effective as a fortificant, the micronutrient form must be bioavailable. In other words, the body must be able to effectively absorb and utilize the micronutrient. In addition, the chosen fortificant must not affect the color or taste of the fortified rice. Different forms of micronutrients have varying degrees of bioavailability and degrees to which they affect the appearance and taste of fortified rice.

The most commonly used micronutrients and their fortificants are discussed below.

Iron

Different forms of iron offer trade-offs between bioavailability and properties impacting consumer acceptance. The iron fortificants recommended for wheat and maize flour fortification (e.g. ferrous sulfate, ferrous fumarate or sodium iron EDTA) are nearly unnoticeable to the consumer because the relevant iron fortificant is equally distributed throughout the fortified flour. However, when concentrated in a fortified kernel, color and taste may be affected. **Figure 5** shows rice that has been fortified with various types of iron, sometimes resulting in fortified kernels that may not be acceptable to consumers.

Ferric pyrophosphate (FePP) is recommended for rice fortification as it does not affect the color of fortified kernels and thus does not negatively influence consumer acceptability. However, the bioavailability of FePP is not as high as of ferrous sulfate, and the total iron that can be added to the fortified kernels is relatively low. A micronized form of FePP can increase bioavailability to some extent. Ferric orthophosphate is sometimes used since it is a nearly white powder; however, bioavailability is below that of FePP.[4,5]

Recent research by the Swiss Federal Institute of Technology (ETH Zurich), confirms that adding a chelating agent can greatly improve the bioavailability of FePP in rice, matching the bioavailability of ferrous sulfate.[6]

Zinc

Adding zinc to rice is relatively easy. Zinc oxide is suitable for the technical needs of fortification and has high bioavailability, with virtually no negative impact on taste, color, or stability for the other micronutrients. Zinc sulfate ($ZnSO_4$) is less suitable, as it may have a negative impact on vitamin A stability.

Selenium

Where selenium deficiencies exist – for example, in Costa Rica – the preferred form for fortification is sodium selenite.

Vitamins

Similar to wheat and maize flour fortification, **the water-soluble vitamins B_1 (thiamin), B_3 (niacin), B_6 (pyridoxine), B_9 (folic acid), and vitamin B_{12} (cobalamin)** are frequently used to fortify rice without affecting acceptability. However, there are some stability concerns with respect to vitamin B_1 when fortified rice is stored at elevated temperatures. Vitamin B_2 (riboflavin) changes the color of the fortified kernels, which reduces consumer acceptability. It is therefore not typically added to rice even when there is a public health need.

Vitamin A is a fat-soluble vitamin commonly used to fortify vegetable oils, but also wheat and maize flour. The preferred form is retinyl palmitate, in combination with a powerful antioxidant, such as butylated hydroxytoluene (BHT). This ensures stability during storage. Among the vitamins used in rice fortification, vitamin A is the most sensitive to the environment and preparation, including such factors as light, heat, and pH.

FIGURE 4: Production methods for batch and continuous blending to produce fortified rice

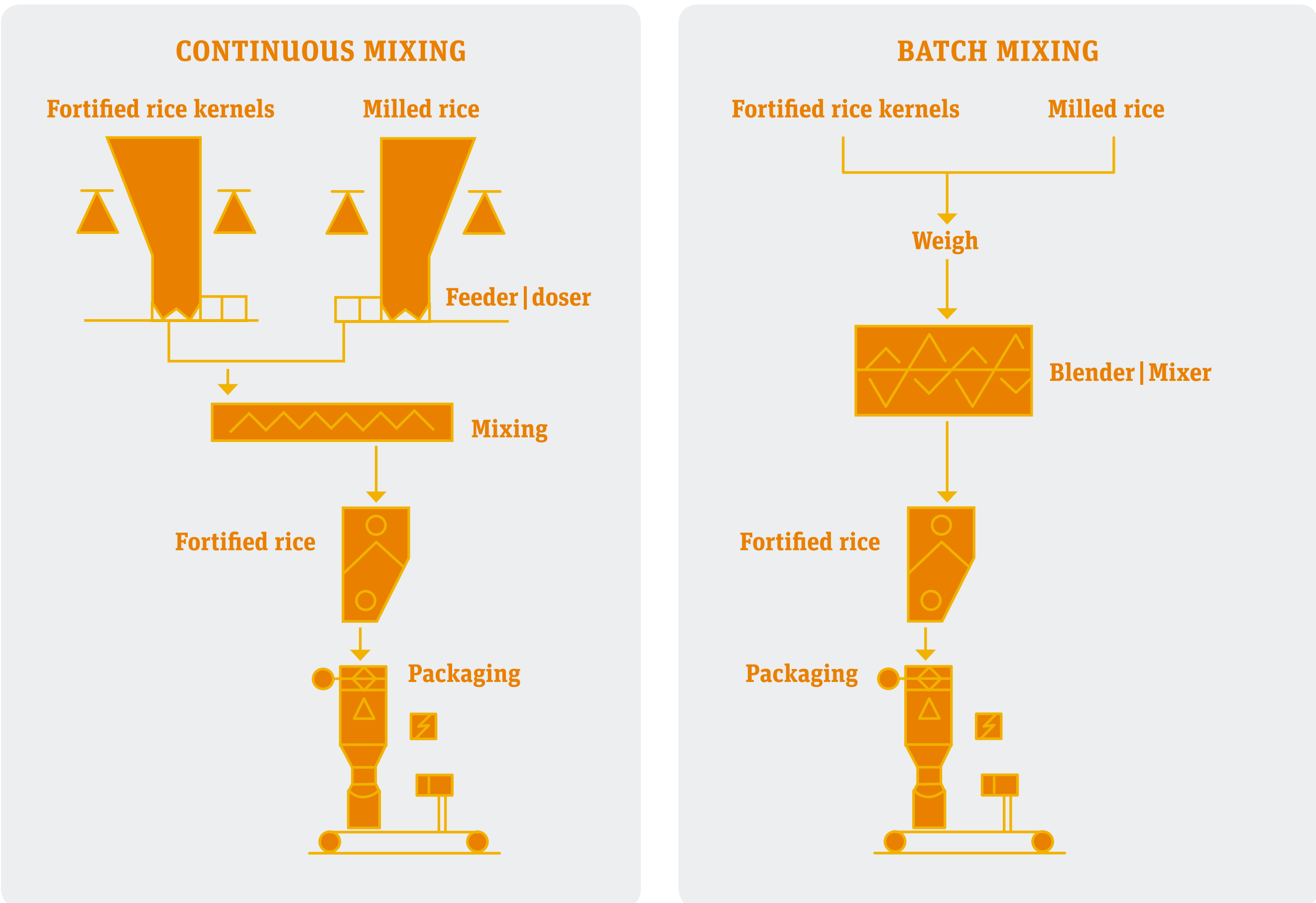


FIGURE 5: Visual appearance of rice fortified with various forms of iron

Some countries also fortify with vitamin E, using a spray-dried α-tocopheryl acetate form. Vitamins D and K are possible in rice fortification; however, they are not yet used in any of the rice fortification programs.

Other

Overall, rice is a good source of amino acids except for lysine; therefore, fortification with lysine can increase the biological value of rice protein. Although the recommended form is highly water-soluble, the majority of lysine in extruded fortified kernels is retained during washing and cooking.[2]

> "The technology for effective fortification is now available for rice, the world's second most commonly consumed cereal grain"

Conclusion

The technology for effective fortification is now available for rice, the world's second most commonly consumed cereal grain. The choice of technology must take into account retention of nutrients during preparation (soaking, washing and cooking), and consumer acceptability (taste, shape, and color). The use of rinse resistant coating or extrusion (hot or warm) to produce fortified kernels meets nutrient retention and consumer acceptablity requirements. Both technologies involve a two-step process: first, production of the fortified kernel, and second, blending of fortified kernels with non-fortified rice.

The fortificant used is also important as it influences consumer acceptability and the effectiveness of fortified rice for public health.

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Standards and Specifications for Fortified Rice

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Key Messages

- Standards and specifications for fortified rice should specify quality in terms of safety, acceptability and nutrient content, for the benefit of consumers and manufacturers.
- Drafting standards and specifications should be a consultative process.
- Codex Alimentarius provides global standards for rice and for food fortification.
- Micronutrient levels should be set such that the intake of the micronutrient in the general population, from all sources, is above the estimated average requirement (EAR) and below the tolerable upper limit (UL) for almost everyone.
- Where intake is not well known and dietary deficiencies are likely, setting the micronutrient level of fortified rice such that, at prevailing consumption levels, it provides the EAR for adults is a good approach.[1,2]

Introduction

When a country chooses to fortify rice to increase micronutrient intake across the population, standards that specify the required quality and nutrient content provide clarity and protection for both manufacturers and consumers. These standards help ensure the nutritional quality of the rice and that the rice is safe and acceptable for consumption. Standards are more general than specifications or Commodity Requirement Documents (CRD). For example, fortified rice standards might cover a range in terms of the types of rice, nutrient content and quality specifications. Specifications for rice for a contract, such as from a government for distribution under a social safety net scheme, are more specific, including, for example, the type of rice, the quality in terms of percentage of broken kernels that can be included, the micronutrient content to be met, the technology/ies used to produce fortified kernels, the blending ratio of fortified kernels to rice grains, the required packaging, the limits for foreign matter and heavy metals, and the shelf-life.

> "Standards that specify the required quality and nutrient content for fortified rice provide clarity and protection for both manufacturers and consumers"

This paper discusses standards and specifications that exist or are being developed for fortified rice, and how to set the desired micronutrient content of fortified rice.

Codex Alimentarius standards

The global source for food standards is the Codex Alimentarius Commission (www.codexalimentarius.org), established by the Food and Agriculture Organization of the United Nations and the World Health Organization (WHO) in 1963. This Commission develops harmonized international food standards, guidelines, and codes of practice to protect the health of the consumers and ensure fair trade practices. The Commission also promotes coordination of all food standards work undertaken by international governmental and non-governmental organizations. While the adoption of Codex recommendations is voluntary for countries, Codex standards are often the basis for national legislation.

For fortified rice, two Codex documents can be referenced: the Codex standard for rice (Codex stan 198-1995[3]) and the guideline for the addition of essential nutrients to foods (CAC/GL 09-1987, amended in 1989 and 1991[4]), which governs fortification of foods in general. There is no Codex standard or guideline specifically for fortified rice; nor is there a guideline specifically for other fortified staple foods. Countries should decide whether to have the same structure, i.e. a standard for rice and a standard for food fortification, and then develop specifications for individual fortified foods, such as fortified rice, that are for a particular use or for particular contracts. These specifications can include more details (e.g., micronutrient content for specific target groups, packaging specifications, etc.) and can be modified more easily when required. Standards and specifications should be developed through a consultative process that includes public- and private-sector partners, academia and civil society. Countries that have developed a standard for fortified rice include Costa Rica, the Philippines and the USA.

> "Standards and specifications should be developed through a consultative process"

Setting the micronutrient content

The level of micronutrients for fortified rice should be determined after consideration of four country-specific conditions.[5]

- **First:** the consumption levels of the food in the target population: if average consumption is high, as in most rice-consuming countries, lower amounts of micronutrients are needed per kilogram of rice to achieve a target level of micronutrient intake.
- **Second:** whether other foods are fortified and with which nutrients: for example, if vegetable oil or sugar are adequately fortified with vitamin A and these foods are consumed by the same people who will consume fortified rice, vitamin A may be included at a lower level in the fortified rice, or not at all.
- **Third:** whether the food, and the diet in general, contains compounds that may affect stability or absorption of minerals or vitamins that are added, such as the phytate in grains that inhibits mineral absorption (e.g., iron and zinc); this information affects the form and level of the nutrient to be added for fortification (e.g., sodium iron EDTA is the only recommended form of iron for fortification of high extraction flour).[6]
- **Fourth:** consumer acceptability: the micronutrient fortification levels and technology used to produce the fortified kernels should be such that the rice is acceptable to the consumer in terms of appearance (color and shape), smell and taste, both before and after preparation.

If rice will be the only food fortified with the specific micronutrient(s), the level of the micronutrient should be set to provide approximately the estimated average requirement (EAR) of the micronutrient(s) for healthy adults. The EAR is the average (median) daily nutrient intake level estimated to meet the needs of half the healthy individuals in a particular age and gender group. The EAR is used to derive the recommended nutrient intake (RNI). The RNI, established by FAO/WHO, is set at the EAR plus two standard deviations, which means that it would meet the needs of 97.5% of all normal, healthy individuals in an age- and sex-specific population group (see **Figure 1**).

Most people already consume some amount of the specific micronutrients. Therefore, setting the micronutrient contribution from the fortified food at the EAR level shifts the average micronutrient intake to a level above the EAR and likely just above the RNI (see **Figure 2**). The proportion of people below the EAR should be less than 2.5% of the population, to minimize the proportion of people that do not receive adequate amounts of the micronutrient to meet their needs.

The fortified rice should make a good contribution to intake for most consumers and at the same time be safe for those who have the highest rice intake. To assess the risk of too high an intake, one has to refer to the tolerable upper limit (UL). The UL is defined as the daily nutrient intake level that is considered to pose no risk of adverse health effects to almost all (97.5%) healthy individuals in an age- and sex-specific population group. The UL applies to daily intake over a prolonged period of time, and to healthy individuals with no micronutrient deficits to be corrected. The UL includes a large safety margin as it is set at a much lower level than the lowest level at which an adverse effect of a chronically high intake has been observed.

Note that the level at which acute toxicity may occur is well above the UL level. Furthermore, as the UL is well above the RNI, and rice will be fortified at a level to provide the EAR, which is approximately 70% of the RNI, one would have to consume several times the expected daily amount of fortified rice in order to reach the UL. Thus, if 300 g of uncooked rice provides the EAR, only consumption of approximately 1–10 kg (depending on the micronutrient) of uncooked rice daily over a prolonged period of time could potentially put the consumer at risk of too high an intake from consuming fortified rice (consistently going over the UL). This scenario is unrealistic.

Determining the micronutrient level per 100 g of fortified rice that is required for the total fortified rice intake to provide

FIGURE 1: Normal distribution of nutrient needs, where 50% of the population meets their requirements at the level of the estimated average requirement (EAR) and 97.5% meets requirements at the level of the recommended nutrient intake (RNI)

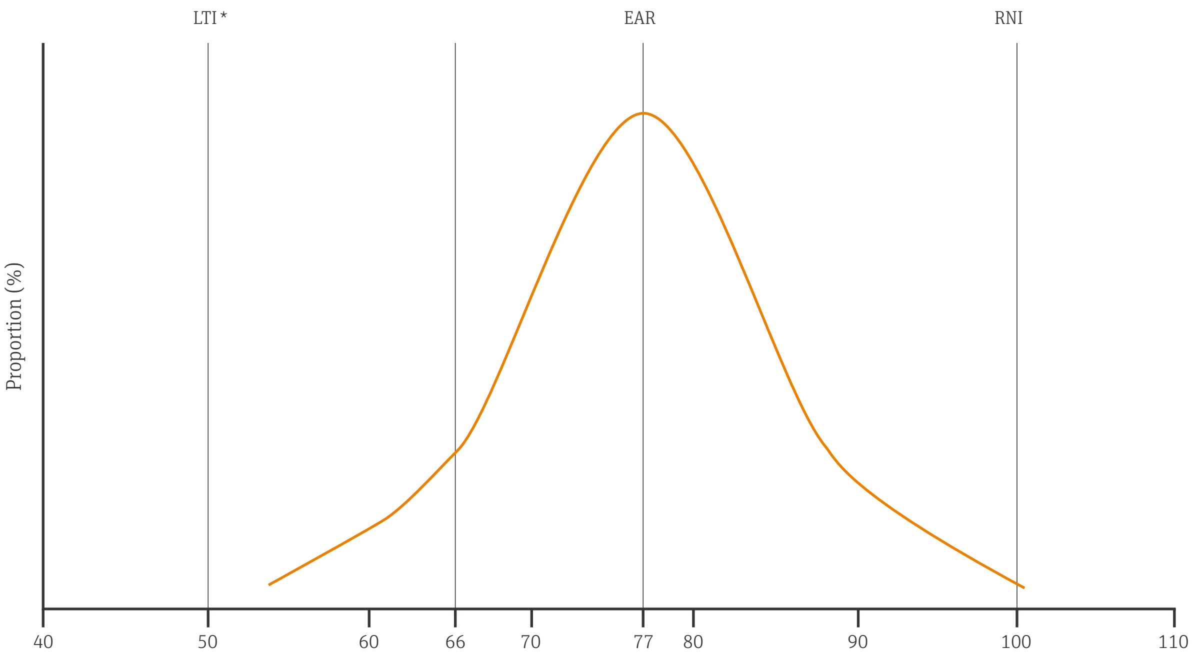
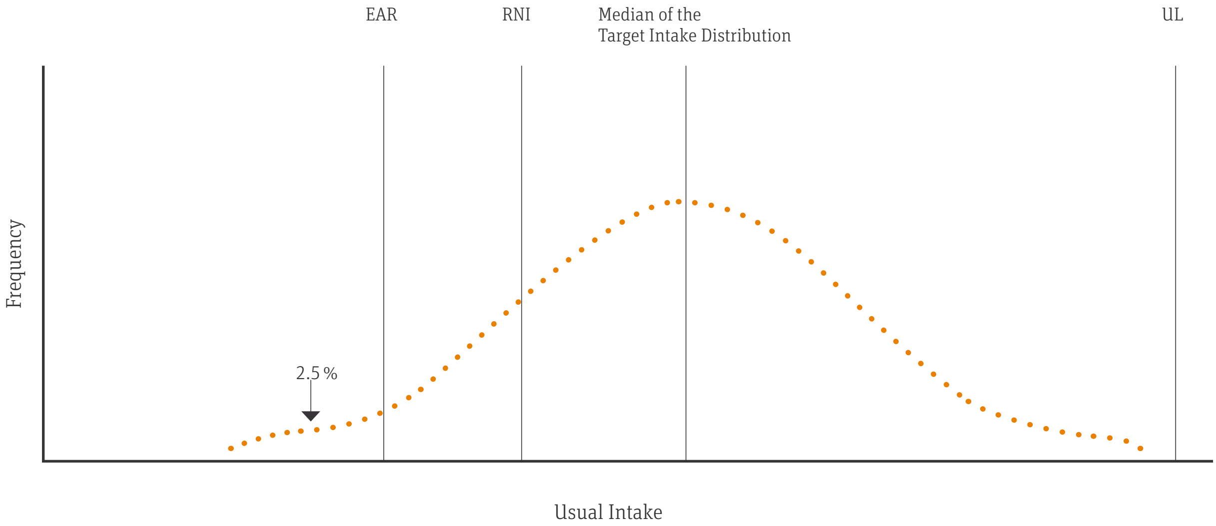


FIGURE 2: The target for micronutrient intake distribution, where 2.5% or less is below the EAR and the majority is above the RNI but below the tolerable upper limit (UL)



the EAR requires an estimate of the per capita rice consumption. For example, the EAR for vitamin B_1 (thiamin) is 0.9 mg for adult women and 1.0 mg for adult men. This means that the amount of fortified rice consumed in a day should provide approximately 0.9 –1.0 mg of thiamin. The interim consensus statement on flour fortification proposed the following categories for flour consumption: ‹ 75 g/d, 75 –149 g/d, 150 –300 g/d, and › 300 g/d.[6] The same categories have been adopted for rice consumption. In countries where rice is the main staple food, average per capita rice consumption typically falls into the higher categories. In the case of thiamin, a level of 0.5 mg/100 g is proposed for the category of 150 –300 g/d

TABLE 1: Nutrient levels proposed for fortified rice at moment of consumption[2]

Nutrient	Compound	<75 g/d	75–149 g/d	150–300 g/d	>300 g/d	EAR
Iron	Micronized ferric pyrophosphate	12	12	7	7	
Folic acid	Folic acid	0.50	0.26	0.13	0.10	0.192
Vitamin B_{12}	Cyanocobalamin	0.004	0.002	0.001	0.0008	0.002
Vitamin A	Vitamin A palmitate	0.59	0.3	0.15	0.1	0.357 (f) 0.429 (m)
Zinc	Zinc oxide	9.5	8	6	5	8.2 (f) 11.7 (m)
Thiamin	Thiamin mononitrate	2.0	1.0	0.5	0.35	0.9 (f) 1.0 (m)
Niacin	Niacin amide	26	13	7	4	11 (f) 12 (m)
Vitamin B_6	Pyrodoxine hydrochloride	2.4	1.2	0.6	0.4	1.1

and 0.35 for › 300 g/d, as these would provide approximately 1.0 mg of thiamin per day at a consumption of 200 g (200 x 0.5/100 g) or 300 g (300 x 0.35/100 g), respectively.

Nutrients and nutrient levels for rice fortification have been recommended based upon this consideration of the EAR and average per capita rice consumption (**Table 1**). For more information on the rationale for choice of the eight recommended micronutrients for fortification of rice, please refer to the contribution by de Pee et al (p. 143) and de Pee[2] (note that research conducted after the paper by de Pee was published has found a possible way of increasing iron bioavailability in rice so that lower levels may be included of approx. 4 mg/100 g instead of 7 mg/100 g in the 150–300 and › 300 g/d categories).[7]

As mentioned above, when there are already other good sources of specific micronutrients consumed by a population, such as vitamin A fortified vegetable oil, or parboiled rice which has higher levels of thiamin, niacin and vitamin B_6 than polished rice, the levels proposed in **Table 1** should be adjusted to meet that population's specific needs. In the case of fortified vegetable oil, the average intake level of vitamin A can be calculated from the per capita consumption of vegetable oil and its fortification level. For example, if the vegetable oil provides 50% of the target EAR, the remaining 50% could be added to rice.

Table 1 and the above explanation have specified levels of micronutrients at the moment of consumption. However, as losses may occur over time, i.e., during storage, and during processing and preparation, an overage may be added at the moment of production, especially for vitamins that are heat-sensitive. Vitamin A is the most heat-sensitive and will require more overage, while other nutrients are more stable. In addition, since there will be variation around the amount of micronutrients that are in the premix and in the fortified kernels, the blending ratio, and the laboratory measurements, specifications for fortified rice also need to specify a minimum–maximum range at the moment of production. Finally, specifications should also specify the allowed minimum content by the best-before date (i.e., the end of the rice's shelf-life).

"Rice fortification should be part of an integrated strategy for improving micronutrient intake and status of a population"

Introducing fortified rice among other fortified foods

Rice fortification should be part of an integrated strategy for improving micronutrient intake and status of a population. Therefore, as mentioned above, when there are other fortified foods, the fortification and consumption levels of those and of other main sources of the specific micronutrients need to be taken into consideration when setting the micronutrient fortification levels for rice. A program such as the Intake Monitoring, Assessment and Planning Program (IMAPP)[8] can assist in calculating safe intake levels of the proposed micronutrients. The program integrates data on the intake of specific foods and additional supplementation among specific target groups, using a food frequency method and a 24-hour recall method.

Conclusion

Standards for a specific category of foods (e.g., rice or food fortification in general) and specifications for a specific food (e.g., fortified rice that the government will buy for the social safety net program) aim to protect the health of consumers and to provide for fair trade practices for those in the rice supply chain. These standards and specifications define quality, in terms of what is safe (e.g., foreign matter), acceptable (e.g., maximum proportion of broken kernels), and nutritious (nutrient content). Standards and specifications should be clear, without the need for further interpretation, and should also be feasible to achieve, monitor, and enforce. Experience demonstrates that standards and specifications are best developed through a consultative process, led by a government's food regulatory authority, informed by Codex Alimentarius and data, and supported by expert groups. This article has reviewed the rationale for the proposed nutrient levels for fortified rice, which can be used as is, or else adapted to a specific country context, taking existing food fortification and micronutrient intake levels into account.

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Identifying Appropriate Delivery Options for Fortified Rice

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Key Messages

- To identify the optimal delivery option for fortified rice, decision-makers should assess the public health need, the rice supply chain, the feasibility of rice fortification, and the extent and scale to which social safety nets reach groups that can most benefit from rice fortification.
- Mandatory rice fortification offers the best opportunity to maximize the public health benefit.
- When the rice milling landscape is fragmented and mandatory fortification is not feasible, the fortification of rice distributed through social safety nets is an alternative to achieve public health impact in targeted populations.

Introduction

Where rice is an important staple food, rice fortification has the potential to significantly contribute to the reduction of micronutrient deficiencies in a population. Fortified rice can reach consumers through three different delivery options. First, governments can mandate that all rice on the market be fortified. Alternatively, rice millers can voluntarily fortify rice in response to market demand. Third, fortified rice can be distributed through social safety net programs. The distribution of fortified rice through social safety net systems can occur alongside either mandatory or voluntary rice fortification. Selecting the most appropriate delivery option depends on public health need, context, and the intended objective and purpose of rice fortification.

This article provides an overview of the three potential delivery channels for fortified rice, lessons learned from implementing countries and current status of rice fortification.

"Selecting the most appropriate delivery option depends on public health need, context, and the intended objective and purpose of rice fortification"

Delivery Option 1:
Mandatory fortification

Mandatory fortification requires food producers, both of domestic and of imported food, to fortify the particular staple food or condiment with specified micronutrients. In comparison with other delivery options, experience shows that mandatory fortification has the greatest potential for public health impact. This results from the consumption of the fortified food by all segments of the population, without requiring behavior change. Governments tend to institute mandatory fortification when micronutrient deficiencies, or the risk of micronutrient deficiencies, are widespread, and when a suitable food vehicle that is consumed by the majority of population can be effectively fortified.[1] Mandatory fortification requires considerable government will, advocacy, and leadership to create the necessary legislation and monitoring system.

Current status of mandatory fortification

Five low- and middle-income countries have mandatory rice fortification, but only three countries have successfully implemented programs so far, as rice fortification is still rather new (**Table 1**). Costa Rica has the most successful mandatory rice fortification program, with 100% of rice fortified. The country also mandates fortification of other staple foods, such as wheat and maize flours, milk, and oil, so the population's improvements in nutrient status are difficult to attribute specifically to rice fortification. Papua New Guinea has also been successful

TABLE 1: Status of rice mandatory fortification, by country.

Country	Legislation year	Rice source, fortified kernel source & milling industry	75–149 g/d
Costa Rica	2001	40% imported; 2 domestic fortified kernel producers; 11 mills	100% fortified
Nicaragua	2009	80% rice domestically grown; 40+ mills, many small	Limited implementation
Panama	2009	40% rice imported; initial plan for government to pay for kernels	Not being implemented yet
Papua New Guinea	2007	All rice imported; fortified with imported kernels or in country of origin	At least 80% fortified (market share of largest importer
Philippines	2001	13% imported; ~11,000 mills. Fortified kernels imported plus 3 domestic producers. SSN rice	1–2% total rice fortified 2006–2013. Currently <1%

in implementing a mandatory rice fortification program. The country's success is facilitated by the fact that almost all rice is imported rather than domestically grown. Moreover, the rice is imported by a small number of rice importers, the largest of which (with an estimated 80% market share) fortifies all its rice. Other importers in the country are believed to be fortifying at least some of their rice. The United States is the third country with mandatory rice fortification legislation. Federal legislation requires that rice must be fortified if it is produced in, goes to, or passes through, a state with mandatory legislation. Six of the US's 50 states have mandatory legislation, and have effectively leveraged their legislation so that an estimated 70% of the US rice supply is fortified.

The other three countries with mandatory fortification have struggled to operationalize and enforce rice fortification. The Philippines passed mandatory legislation in 2001 and has undertaken significant planning and investment for rice fortification, yet less than 1% of total rice is currently fortified. Initially the government put in place a work plan that projected implementation in phases, with the largest mills fortifying first. The National Food Authority (NFA), which implements a large social safety net program of subsidized rice, then conducted efficacy, effectiveness and acceptability trials of fortified rice, and purchased blenders and fortified kernels to fortify their rice at NFA warehouses. Multiple sub-national governments passed local ordinances requiring all rice to be fortified. However, despite these efforts, the private sector never started rice fortification on a large scale, primarily due to a fragmented milling industry landscape and the low fortification capacity of the thousands of small millers. There are also additional problems of technology constraints, the complexity of the supply chain for fortified kernels, and geographic logistical challenges. At this time, even the NFA rice is not being fortified, due to problems with logistics, finances and consumer uptake. As a result of these challenges, the government has not actively tried to enforce universal rice fortification.

Similarly, the governments of Nicaragua and Panama are not actively enforcing their rice fortification legislation. Again, these countries are also hampered by the high fragmentation of the rice milling industry and low industry capacity for fortification.

Lessons learned from mandatory fortification

Mandatory fortification provides the greatest opportunity for large-scale, sustainable public health impact

Although there are few mandatory rice fortification programs being implemented today, extrapolating from rice fortification efficacy studies and lessons learned from other staple food fortification (e.g., wheat flour) and condiments (e.g., salt) there is every reason to believe mandatory rice fortification would be an effective and cost-effective strategy to improve micronutrient intake. For more information, please refer to the case study on Costa Rica, in the contribution by Tacsan et al (p. 212).

Political will is necessary to establish mandatory fortification

Political will and commitment are required to pass national legislation requiring the addition of specific micronutrients to the identified food, and to set national standards. Thereafter, continued political will and government capacity are necessary to implement regulatory monitoring systems for effective enforcement of the legislation and standards.

As with all mandatory food fortification programs, mandatory rice fortification programs are only effective when enforcement is in place

Comprehensive legislation and strong enforcement create an enabling environment to ensure a sustainable and cost-effective supply of fortified rice. Legislation, once passed, must be enforced. However, generating sufficient political will, manpower, and resources to effectively enforce the legislation has been challenging in half of the countries with mandatory rice fortification legislation. Enforcement and regulation function to level the playing field and provide the private sector with the assurance that their competitors will incur the same costs. These measures also ensure the fortification of the entire rice supply.

Mandatory fortification, including mandatory rice fortification, has minimal impact on consumer pricing

When fortified rice is mandated, consumers do not need to choose between fortified and non-fortified rice, as all the rice on the market will be fortified. Therefore, consumers do not have to change their buying habits and will not have to pay a premium price for fortified brands. In this scenario, rice millers will most probably pass on the additional costs of fortification to consumers. These costs are likely to be minimal, and will be shared across all the rice available in the market. In fact the average consumer may not notice the increased cost. In some contexts the government may choose to pay for the cost of fortification, or millers may choose to not pass on fortification costs to consumers.

The degree of industry consolidation, size, and modernization contributes to the success of rice fortification

In many rice-producing countries, rice milling has traditionally been done on a very small scale, such as one mill per village. Today, the global industry is slowly modernizing and consolidating. As demonstrated by Costa Rica, a consolidated manufacturing base facilitates the achievement of universal rice fortification. In the Philippines, the fragmented milling structure has been a significant constraint to the implementation of mandatory rice fortification legislation.

Industry investment is necessary to develop domestic capacity for fortified kernel production

The volume of fortified kernels required to fortify a country's rice supply is considerable. Therefore, the associated transport costs of importing fortified kernels can be prohibitive. Private companies will only invest in the manufacturing facilities for fortified kernels if they are confident that national governments will enforce the legislation and that millers will comply with it. Alternatively, fortified kernel producers outside the country will only significantly increase their production capacity and be in a position to sell their products at rates that compensate for transport costs if they believe that there will be a sustained market for their fortified kernels. Millers also need to make investments in feeder and blending equipment and to purchase fortified kernels. Prior to developing domestic capacity for kernel production, players in the supply chain will need to evaluate the government's political will, manpower, and resources before committing their own resources.

Marketing, including communication for behavior change, is not necessary to influence purchasing decisions when rice fortification is mandatory

When mandatory legislation is in place and enforced, marketing and communication costs are minimal. It remains important to inform consumers that their rice is now fortified and to provide labelling that indicates the type and level of the additional nutrient content. There is no need, however, for either rice producers or the government to undertake costly marketing or other communication activities to encourage people to purchase fortified rice.

Delivery Option 2:
Voluntary fortification

Fortification is voluntary when the private food industry has an option whether or not to fortify products. Voluntary fortification is a business-oriented approach, with fortified food products marketed as "value-added" products, often targeted at higher-income consumers. If millers perceive a current, potential or emerging demand for fortified rice, they may choose to develop a fortified brand to increase sales or profits. The potential for influencing a population's micronutrient health through voluntary rice fortification will be low. This is due to the uncertainty of industry uptake and consumer demand. Impact will also be limited as lower socioeconomic groups, who are most in need of fortification, are the most unlikely to purchase fortified brands due to their higher cost. Consumer aversion to changing rice preparation, cooking and eating habits, and product unavailability in typical channels, such as bulk sales, also limits the potential impact of voluntary fortification. Additionally, there is no evidence that voluntary fortification leads to mandatory fortification.

Status of voluntary fortification

Four countries have large-scale voluntary rice fortification programs, in addition to numerous other small-scale fortification efforts throughout the world. Columbia has a relatively consolidated rice industry; seven millers fortify rice and produce about 50% of the market supply. Unfortunately, Columbian millers use a coating fortification technology that is vulnerable to nutrient loss after preparation and cooking. This reduces the public health benefit. This ineffectual fortification method demonstrates that the lack of national standards is the key weakness of voluntary fortification. In Brazil and South Africa, where implementation has not been achieved at large scale (only an estimated 1–4% of rice is fortified), the rice millers are fragmented, and consumer awareness and motivation to purchase the premium-priced rice brands is low. The current status of implementation in the Dominican Republic is not known.

Lessons learned regarding voluntary rice fortification

Difficult to achieve broad public health impact

Voluntary rice fortification has not achieved high and sustained coverage of the total rice supply, except in unique situations, such as in Columbia, where industry consolidation facilitated agreement between millers to fortify. Without much coverage of the fortified product, in particular among the most poor and vulnerable populations, the health benefits will be limited.

Standards are necessary, even in voluntary fortification

Voluntary rice fortification also requires appropriate standards for rice fortification. As evidence from Columbia demonstrates, the benefits of convincing millers to voluntarily fortify were offset by ineffective fortification standards. The lack of effective voluntary standards in Colombia has enabled rice producers to market fortified rice that is unlikely to provide nutritional benefit.

Government regulations and enforcement are still necessary in a voluntary system

Although the private sector determines whether to fortify, governments still have a significant role to play in setting standards and regulations for fortification. In the context of voluntary fortification, governments also have to undertake compliance monitoring and enforcement so as to ensure that fortified products meet national standards, that they are safe and correctly labeled, and that unsubstantiated health claims are not made.

Fortified rice brands are likely to be more expensive

Millers will typically raise retail prices to cover the increased costs of manufacturing and marketing fortified brands. If the fortified rice brands are being sold as value-added products, the price increase may be in excess of production and marketing costs, as producers will often position the fortified rice as a luxury product.

Increased marketing (i.e., advertising, promotion, and packaging) is needed to promote the benefits of the fortification and the premium pricing

Contrary to popular belief, marketing and social mobilization campaigns aimed at encouraging consumers to purchase fortified foods, including fortified rice, have failed to convince large segments of the population to choose fortified products. However, with voluntary fortification, consumers are offered a choice of value-added, higher-priced fortified rice or lower-priced, unfortified rice at the point of sale. Therefore, in order to increase sales of fortified products, there is no other choice than for rice producers or governments to undertake and maintain marketing and social mobilization campaigns.

Delivery Option 3:

Fortification of rice distributed through social safety nets

Targeted rice fortification can be achieved by fortifying rice distributed through social safety nets, such as school feeding programs, distributions to the poor or to vulnerable groups, food for work programs, and food aid during emergency situations. Fortifying rice distributed in social safety net programs reaches the most vulnerable populations, and thus has the potential to make a significant impact on public health. The fortification of rice distributed through social safety nets can be implemented in parallel with mandatory or voluntary fortification. It can also function as a catalyst for mandatory fortification.

Status of fortification of social safety net rice

Five countries currently distribute fortified rice through social safety net programs, which are primarily implemented by governments with funding from governments or donors. The most successful of these is the inclusion of fortified rice in the Bangladesh Government's Vulnerable Group Feeding/Development program.

On a smaller scale, in Odisha state in India, the UN World Food Programme (WFP) is supporting the distribution of fortified rice with Indian-made fortified kernels blended into the non-fortified rice at the district level through the platform of the government's school feeding program. Based on the findings of the ongoing evaluation, the State government will explore expansion through the entire state's school feeding program.

In Indonesia, the RASKIN subsidized rice program for the poor implemented a pilot program to fortify rice distributed in a limited area. Efficacy and effectiveness studies of the impact of the distributed fortified rice have been commissioned. Depending on the results, fortification may be scaled up to all RASKIN distributed rice. Ultimately, the potential impact of fortification of RASKIN rice will depend on how well the social safety net itself is functioning. It has been reported that both suboptimal beneficiary targeting and social stigmatization resulting from the use of low-quality rice has limited effectiveness of the RASKIN program. In addition, before the pilot can be expanded, logistical challenges – such as the development of sufficient domestic capacity to produce fortified kernels and cost-effective opportunities to blend the fortified kernels with the non-fortified rice – require resolution.

In the Philippines, the National Food Authority (NFA) has enjoyed only limited success at fortifying subsidized rice. Budget constraints have limited production quantities and beneficiary coverage. In addition, the NFA purchased colored fortified kernels in order to differentiate the subsidized rice from private-market rice. As a result of this differentiation, the colored kernels have reduced the acceptability of the fortified rice among some consumers. NFA is now considering resuming fortification with non-colored kernels, assuming that funding can be secured.

Lessons learned from fortification of rice distributed through social safety nets

Social safety net programs that include rice distribution offer a good opportunity to target fortified rice to those most in need

In situations where mandatory fortification is not possible, social safety nets may be the only delivery option for fortified rice that will achieve a public health impact. However, the public health impact will be limited to the beneficiaries of the social safety net.

Fortification of rice distributed through social safety nets can act as a catalyst for mandatory fortification

Fortification of rice in social safety nets establishes supply chains for fortified kernels and capacity for the production of fortified rice. It also provides opportunities to establish the effectiveness and acceptability of fortified rice among domestic consumers. Information on rice fortification and experience obtained through social safety net programs can increase government commitment to mandatory rice fortification.

Enforcement and regulation

The fortification of rice distributed through social safety net programs is unlikely to require national legislation, but it will require the social safety net implementer to make a policy decision and to establish or adopt a standard for fortified rice supplied in the social safety nets.

The social safety net implementer typically bears the cost of fortification

Social safety nets are often funded and implemented by the government, philanthropic organizations, or the private sector as part of their Corporate Social Responsibility activities. Rice millers and manufacturers will be invited to bid to supply the program. These private sector agents will have a guaranteed market with low risk, at a price that usually covers their increased manufacturing costs for a defined period of time. As the social safety net implementer is bearing the cost of fortification, the consumer will not be subject to a price increase.

Fortification costs may be substantial

Although the fortification manufacturing cost will be a small percentage of the price of the program, compared to the costs of procurement and distribution, the initial capital costs and reoccurring costs may still be considerable. For example, the Philippines' NFA spent over US$1.5 million on blenders and imported fortified kernels but was only able to fortify an average of 15% of the rice distributed by the program between 2006 and 2013 (an average of 160,000 metric tons per year). By contrast, in mandatory fortification programs the cost of fortification is shared by all consumers and possibly millers, in social safety net programs the cost of fortification is often borne by the program funder.

Logistical issues may impede implementation

Several of the social safety net programs have experienced logistical difficulties, such as sourcing the rice for distribution, contracting millers to blend, and sourcing fortified kernels. Challenges also exist in the implementation of the social safety net program itself, such as poor management and corruption, and ineffective and inefficient targeting. Finally, there may be consumer stigmatization as a result of participation in the program, which may be exacerbated by the use of poor-quality rice.

No marketing is needed for fortified rice in a social safety net

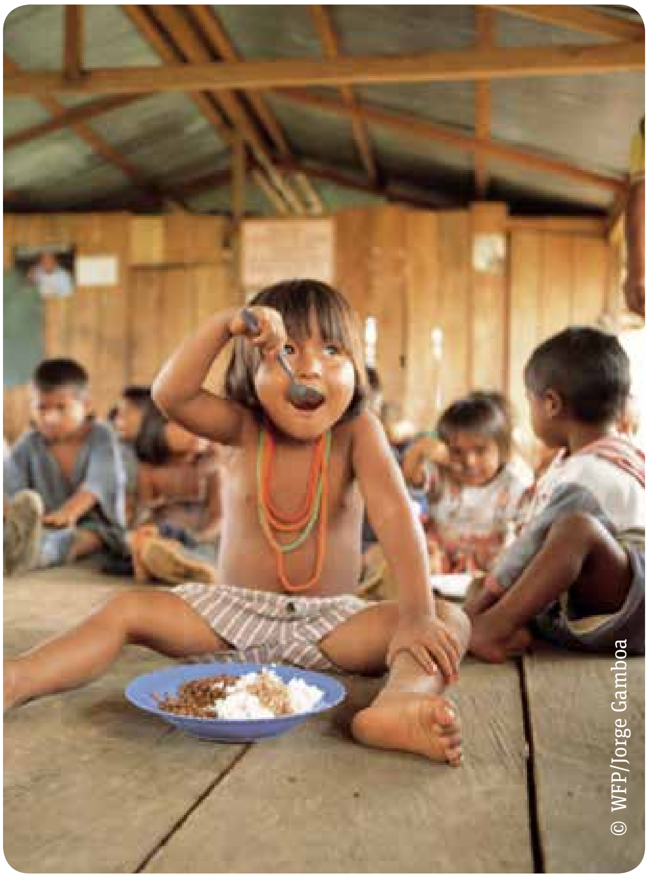
The fortified rice is provided to the targeted population for free or at a subsidized price; the group targeted does not have a choice regarding the brand or type of rice supplied. However, as in all fortification programs, consumers should be informed that the rice is fortified so that they understand its benefits.

Considerations for choosing the optimal delivery option

With the reliance on rice as a staple food throughout Asia and the high prevalence of micronutrient deficiencies in the region, rice should be considered as a major fortification vehicle. The impact will be maximized if high coverage of fortified rice can be achieved in those population groups with nutrient deficiencies. The choice of delivery option should be based on an analysis of the rice supply chain, an assessment of the feasibility of implementation in the given context, and identification of the target group.

Mandatory rice fortification offers the best opportunity to reach the majority of people in a cost-effective and sustainable way. However, mandatory fortification is only possible under certain conditions. Mapping the rice supply chain helps to assess the feasibility of mandatory rice fortification and should include an assessment of the proportion of rice that is milled in mills with fortification capacity, the extent of milling consolidation, the availability of warehouses where it might be fortified, and the most sustainable and cost-effective sources of fortified kernels. If the analysis suggests mandatory rice fortification is feasible, information on the rice supply chain should be used to plan implementation.

Depending on the manufacturing and regulatory landscapes, voluntary fortification rarely achieves high population coverage, and is unlikely to achieve a public health impact for the most vulnerable. Therefore, in places where mandatory rice fortification is not feasible, social safety nets that distribute rice



A child eating his lunch at school, Colombia

offer a good opportunity for reaching the most vulnerable. Planners must analyze the feasibility of integrating fortification into the rice procurement, processing, and distribution process of the social safety net program and estimate funding and quality assurance monitoring requirements. The efficacy and effectiveness of the fortified rice is dependent on how well the social safety net functions.

Conclusions

Mandatory rice fortification offers the best means of achieving high coverage of a population, and hence a public health benefit. Past experience shows that voluntary rice fortification has only achieved high coverage in unique circumstances, such as in Columbia, where industry consolidation facilitated agreement between millers. Social safety net programs that distribute rice are an excellent way of reaching vulnerable groups with fortified rice, and they provide valuable manufacturing and distribution experience. Importantly, assessment of the feasibility of implementation is necessary for both mandatory and social safety net delivery options. A rice landscape analysis will provide essential information to assess feasibility.

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Understanding Factors that Influence the Benefits and Costs of Rice Fortification

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Key Messages

- Fortified staple crops are one of many alternative programs for addressing micronutrient deficiencies in developing countries. Their effectiveness will depend, in part, on the measure of impact selected, and on the diets of target beneficiaries, which can vary spatially and across socioeconomic groups. Their costs will depend on the fortification technologies selected and the scales at which they are undertaken.
- This paper uses detailed dietary intake data from Cameroon to demonstrate the effects of alternative definitions of "success" on predicted program impact.
- This paper also reports cost estimates for medium-scale production of fortified rice kernels in the Dominican Republic and discusses various economic considerations for scaling up rice fortification
- Twin-screw, hot-extrusion technology already exists in the country on both large and medium scales. Based on established medium-scale production technologies, the estimated average cost of producing fortified rice kernels is US$1.76 per kg. Based in rice consumption habits in the Dominican Republic, rice fortification appears to be a good bet for increasing micronutrient intake.
- However some measures of impact (e.g., effective coverage) may suggest that programs other than rice fortification be pursued, perhaps subnationally.
- Regardless of micronutrient intervention program choices, fully funded monitoring and evaluation data collection and analyses will be required.
- Rice fortification has not yet begun in the Dominican Republic and private companies that are set to produce fortified rice kernels are in various stages of trials, and government regulations regarding premixes are still under development.
- Regardless of eventual regulations and despite very high average per capita rice consumption in the Dominican Republic, in this relatively small country excess national capacity for producing fortified rice kernels will likely emerge; underutilized capacity may complicate emerging public/private partnerships and may also increase the cost of a national rice fortification program.

Introduction

Vitamin and mineral (micronutrient [MN]) deficiencies are common in developing and low-income countries, especially among young children and women of reproductive age (WRA) because of their relatively high MN requirements.[1,2,3] The economic consequences can be large,[4,5] and addressing these MN deficiencies is expected to be very cost-effective.[6] Sets of best-bet MN intervention programs have been identified,[7] though gaps in knowledge remain regarding their effectiveness and cost-effectiveness subnationally and over time.[8]

At country level, several choices have to be made before selecting the appropriate MN intervention programs. First, measures of impact must be selected and agreed upon. There are many candidates available, chief among them being:[9]

- **Reach:** the number (or %) of individuals who receive the benefits of a program, regardless of their individual needs or the amounts of MN received;
- **Coverage:** the number (or %) of individuals with micronutrient deficiency who receive the benefits of the program, regardless of the amounts of MN received; and
- **Effective coverage:** the number (or %) of individuals *with insufficient dietary intake who achieve adequate dietary intake* due to program intervention(s).

Different measures of impact will often point to different combinations of cost-effective interventions.

> "First, measures of impact must be selected and agreed upon"

Second, the target beneficiary group or groups should be identified; different groups (e.g., young children versus WRA) may have different MN needs and consume different amounts of different types of foods, therefore one would not expect that food fortification programs would affect all individuals equally.

Third, even in small countries, MN deficiencies might not be distributed uniformly over the landscape; if there are regional differences in needs (north versus south, urban versus rural) and if programmatic options exist, decision-makers may be in a position to choose where to intervene.

Finally, timing often matters in responding to MN deficiencies; some programs are quicker to launch but less cost-effective in the long term, others will require longer start-up periods but may prove to be more cost-effective in the long term. Therefore, combinations of programs that phase in/out over time may be required to deal with pressing MN deficiency issues; developing such a strategy requires a long planning horizon.

This paper touches on the first three of these issues. The next section uses a nutrition benefits model based on nationally representative, individual dietary intake data from Cameroon to demonstrate the differences among indicators of MN intervention program impacts. Section three uses the same model to assess the effects on WRA of the hypothetical rice fortification program in three separate macro-regions of Cameroon. Section four examines the costs of rice fortification in the Dominican Republic using medium-scale, hot-extrusion technology, and assesses national fortified rice kernel production capacity. Section five provides conclusions and some policy implications.

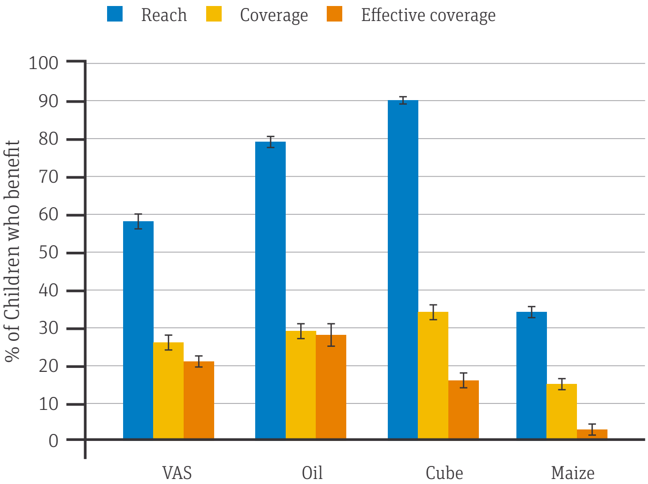
Alternative measures of impact of a MN intervention program

Different measures of impact can yield very different answers to the question "How successful are current/planned MN intervention programs?" **Figure 1** reports estimates generated by the Micronutrient Intervention Modeling Project's (MINIMOD) nutrition benefits model[9] of the reach, coverage, and effective coverage of four alternative platforms for delivering vitamin A (VA) to young children in urban areas in Cameroon: high-dose VA supplementation (VAS) delivered via Child Health Days, fortified edible oils (Oil) and bouillon cubes (Cube) delivered via commercial outlets, and biofortified Maize.[9,10] If simply reaching target beneficiaries is the selected measure of impact, then bouillon cubes, which were consumed by nearly 95% of surveyed individuals on the previous day, is the clear "winner." If reaching only those with VA deficiency is the impact measure, then fortified bouillon cubes, oil and VAS become close competitors, all with measures of predicted impact below 50%. Finally, if the objective is raising the dietary intake of VA among individuals with low intake to adequate VA intake is the objective – i.e., if effective coverage is selected as the impact measure – then fortified oil and VAS are clearly the superior MN intervention programs in this setting, for the program parameters modeled (reach and fortification levels), and for this beneficiary group, but each of these programs fails to reach a large percentage of children in need, signaling the importance of selecting combinations of programs to more completely address VA deficiencies.

Predicting the impacts of fortified rice in Cameroon

Because diets vary spatially and across socioeconomic groups, one would expect that patterns of effects of MN intervention programs would also vary across these dimensions. **Figure 2** shows estimated effects of the hypothetical introduction of fortified rice into the diets of WRA in Cameroon (assuming that 5.9 mg/kg of vitamin A and 95 mg/kg of zinc were added to 100% of rice consumed). The first trio of columns reports the reach of fortified rice; fewer WRA in the South macro-region of Cameroon consume rice, compared to those in the North and City macro-regions, and hence, on average, WRA in the South benefit less from this MN intervention program. Perhaps more

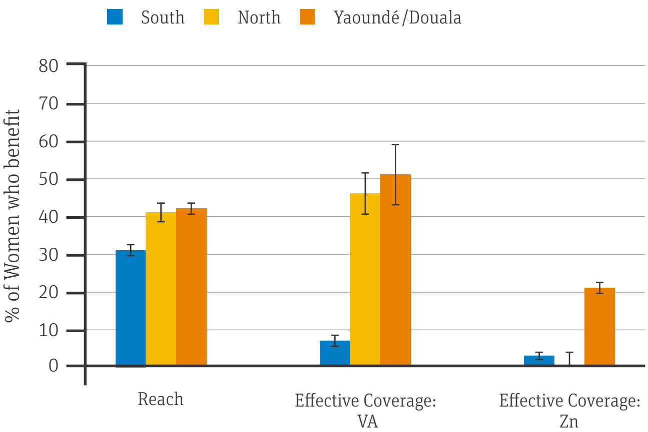
FIGURE 1: Predicted reach, coverage, and effective coverage of alternative vitamin A delivery platforms*: Urban children, 6–59 months of age, Cameroon



*Example data for vitamin A programs delivered to children 6–59 months of age in Yaoundé/Douala (2009). VAS represents high-dose VA supplementation provided via Child Health Day national campaigns. Oil, cube, and maize represent, respectively, fortified edible oil, fortified bouillon cubes, and biofortified maize. Oil assumes measured fortification values (44% target). Cube and Maize assume 100% (bio)fortified.

Source: MINIMOD Project Data, authors' calculations.

FIGURE 2: Predicted effects of rice fortification with VA and zinc*: Women in Cameroon, by macro-region, and by measure of program impact



*Assumes 5.9 mg/kg of vitamin A and 95 mg/kg of zinc were added to rice;[23] 100% of consumed rice is assumed to be fortified in this very optimistic scenario.

Source: MINIMOD Project Data, authors' calculations.

importantly, the second and third trios of columns report effective coverage for VA and for absorbable zinc. Because of inter-macro-regional differences in diets and especially in VA and zinc intakes, WRA in the major cities are predicted to benefit much more from a rice fortification program than their counterparts in the South.

The rice fortification capacity and cost in the Dominican Republic

While several technologies exist for the fortification of rice,[11] not all technologies are appropriate for all developing countries, for both cultural and economic reasons. In the Dominican Republic, as in many developing countries, consumers at all socio-economic levels carefully select out imperfect rice grains and practice intensive rice washing prior to cooking.[12] Therefore, extrusion is likely to be the most viable technology for introducing and preserving adequate levels of micronutrients into rice, as well as for preserving the color and taste of rice that consumers recognize and demand.[12,13] Typically, the high cost of establishment and operation is a barrier to rice fortification via hot extrusion.[14] However, in recent years in the Dominican Republic, private industry has invested in hot-extrusion technology on both large and medium scales. This section explores the estimated costs of medium-scale rice fortification using hot-extrusion technology, and the various economic considerations for scaling up rice fortification using this technology in the Dominican Republic.

> "While several technologies exist for the fortification of rice, not all technologies are appropriate for all developing countries"

Two rice-processing companies have purchased and installed twin-screw hot-extrusion machines, a technology that has been shown to produce reconstituted grains with "superior integrity, flavor, and texture" compared to other types of extrusion or fortification technologies.[15] One company is classified in this paper as a large-scale producer of extruded rice kernels, and the other is classified as a medium-scale producer of the same product. While somewhat arbitrary, the scale distinction used here is based on the type of extrusion technology available at each facility in terms of cost of the extruders and productive capacity (see **Table 1**).

Using average annual rice consumption in the Dominican Republic[16] and assuming a 1:200 fortified-to-non-fortified rice kernel blend,[13,17] the annual national requirements for fortified rice kernels is approximately 2,700 metric tons. Installed medium-scale extrusion technology could meet national demand in approximately one year; installed large-scale technology could do so in about three months. The micronutrient specifications for the Dominican Republic are still under development by the Ministry of Public Health in collaboration with USAID, DSM, regional partners, and other international nutrition research

TABLE 1: Productive capacity of established rice extruders in the Dominican Republic (metric tons of extruded kernels/month)

Medium-Scale *	Large-Scale
240	1,200

* Production capacity of the medium-scale technology is based on running four of five extruders, five days per week, 20 hours per day.

Source: Authors' calculations based on data provided by rice kernel producer.

entities.[13,18] Once these specifications are set, the MN premix for rice kernel extruders will be produced, and producers will fine-tune extruders to guarantee the production of fortified rice kernels that will be essentially indistinguishable by consumers from common grains of rice.

The estimated cost of rice fortification presented below is based on data from a medium-scale hot-extrusion production technology. These data are based on actual establishment costs and expected operational costs. **Tables 2** and **3** provide a summary of estimated costs. The largest drivers of annual input costs are electricity and broken rice (the key input into the extrusion process), which constitute approximately 22% each, and the fortified premix, which constitutes almost 52% of the annual recurring costs.

There are additional private-sector costs not included in this calculation that should be considered. Specifically, private-sector costs of blending and packaging fortified kernels with non-fortified rice kernels are not considered here. If mandatory rice fortification is introduced, small-scale rice millers that lack the technology to produce fortified rice kernels would be required to purchase fortified kernels and the machines to blend them with non-fortified milled rice. Machinery and blending costs are expected to be small and diffused across a large number of rice millers. The cost of fortified rice kernels, on the other hand, could significantly increase overall input costs for all rice millers, especially those engaged in the processing and marketing of lower-quality, broken-grain rice.

Perhaps more important, the public-sector costs associated with managing the rice fortification program, including monitoring of the quality of rice in the wholesale and retail markets, are not addressed here.

"Given the quantities of rice consumed by all segments of the population in the Dominican Republic, rice fortification is one likely cost-effective delivery platform for addressing MN deficiencies"

Conclusions and implications for policy

Given the quantities of rice consumed by all segments of the population in the Dominican Republic, rice fortification is one likely cost-effective delivery platform for addressing MN deficiencies. However, several important caveats apply.

First, while fortified rice may be an excellent platform for reaching targeted beneficiaries, it may not deliver sufficient

TABLE 2: Annual costs of producing fortified rice kernels using medium-scale technology in the Dominican Republic (thousands US$[a])

Principle and Interest on Establishment Costs[b]	US$219
(Includes machines, new buildings/structures, 5.5% compound annual interest)	
Annual Plant Operational Costs[c]	US$1,163
(Includes labor, electricity, maintenance/repairs, quality control)	
Annual Input Costs	US$3,692
(Includes broken rice, vitamin and mineral premix)	
Total Annual Costs[d]	**US$5,074**
(Excludes blending, packaging, public sector costs)	

[a] 2016 US$

[b] Assume a 5.5% compound annual interest rate and an expected life of extruders and buildings of approximately 10 years according to private industry estimates.

[c] Production capacity of the medium-scale technology is based on running four of five extruders, five days per week, 20 hours per day.

[d] Based on 2,880 MT annual production. Excludes private-sector blending costs, and public sector program management and M&E costs.

Source: Authors' calculations based on data provided by medium-scale producer during factory visits.

A little Guatemalan girl, 2012

amounts of specific MN to achieve dietary intake targets, especially for young children who have high MN needs relative to their total food intake.

Second, therefore, combinations of MN interventions may be required to achieve overall MN program objectives, and some of these interventions may need to be targeted to specific socioeconomic groups and/or specific regions.[21] Special attention may need to be paid to the rural poor, who tend to consume own-produced, and hence unfortified, rice.[22]

Third, a mandatory rice fortification program will increase the price of rice; which stakeholder groups in society pay this increased price is a policy choice. One option is to pass some or all cost increases on to consumers; given that some of the benefits of rice fortification will accrue to consumers, it is reasonable that they should bear some of the costs. However, the public sector will also likely benefit from rice fortification via, for instance, reduced public healthcare costs, and therefore should shoulder part of the cost. Finally, the various subsectors of the rice economy, including importers, may also be called upon to cover some of the rice fortification program costs. In the end, and as always, identifying which groups in society cover program costs will be a negotiated outcome, and one that should be revisited periodically.

Fourth, installed hot-extrusion capacity in the Dominican Republic already exceeds estimated annual national needs for fortified rice kernel production. Underutilized capacity could raise the cost of nationally produced fortified kernels as well as undermine incentives to invest in extrusion capacity. International sources of fortified rice kernels also exist. Therefore, one key element of the national rice fortification strategy will be to determine the source(s) of fortified kernels, the prices to be paid for them and by whom, and the contractual arrangements linking producers of fortified kernels, downstream millers, and segments of the public sector charged with managing and overseeing the fortification program.

Finally, collecting and analyzing the dietary intake and biomarker data required to monitor, evaluate, and adjust the rice fortification and other MN programs should be a well-funded element of any national MN strategy, and should be put in place before programs are launched.

Acknowledgements

We gratefully acknowledge the important insights and contributions of Dr Susana Santos, Dr Svetlana Afanasieva, and Mr

TABLE 3: Cost to private industry of producing fortified rice kernels using medium-scale technology (US$[a])

Total Establishment Cost of Capital Investments	**US$1,715,860**
(Includes machines, new buildings/structures, labor and electricity for installation and testing)	
Estimated Cost per MT of Fortified Rice Kernels [b]	US$1,762
($5,074,000/year ÷ 2,880 MT/year)	
Cost to Meet Annual National Estimated Fortified Rice Kernel Needs	US$4,757,400
($1,762/MT* 2,700 MT/year)	

[a] 2016 US$

[b] Our estimate of $1.76 US$/kg of fortified rice kernels includes the cost of broken rice as the key input, and falls within the range of costs estimated by other authors, e.g., DSM estimates are $4.10 US$/kg of fortified rice kernels for a premix formulated to address anemia and $2.10 US$/kg of fortified rice kernels for an alternative premix, and Alavi et al. provide an estimate of $1.19 US$/kg of fortified rice kernels.

Source: Authors' calculations based on data provided by medium-scale producer during factory visits.

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The Role of the Private Sector in Rice Fortification

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Introduction

The fortification of staple foods with essential vitamins and minerals is a proven, cost-effective and sustainable intervention to prevent micronutrient malnutrition among entire populations, especially where existing food vehicles and local distribution networks are available and can be utilized. As it is the staple food for an estimated three billion people – most of whom reside in developing countries – making rice more nutritious offers a vast opportunity to improve micronutrient intakes and the health status of entire populations. However, to date rice fortification has been an underutilized public health tool, due in part to the need to ensure the slightly higher costs of rice fortification are appropriately absorbed.

Fortunately, there is broad global experience with fortification of staples such as wheat flour, maize flour, oil, and salt, and some experience in rice fortification. The knowledge gained through these is valuable for implementing and scaling up new rice fortification interventions.

The exact role and interests of the private sector in rice fortification differ based on context and the delivery model chosen. This report outlines the various private-sector actors involved in fortification, as well as the interests and role of those actors in rice fortification, and offers case studies which further illustrate what the critical role of the private sector has been in various delivery models. Together, the insights gained can help the food and nutrition community build, improve and sustain rice fortification programs which achieve impact.

Overview of private-sector actors in fortification

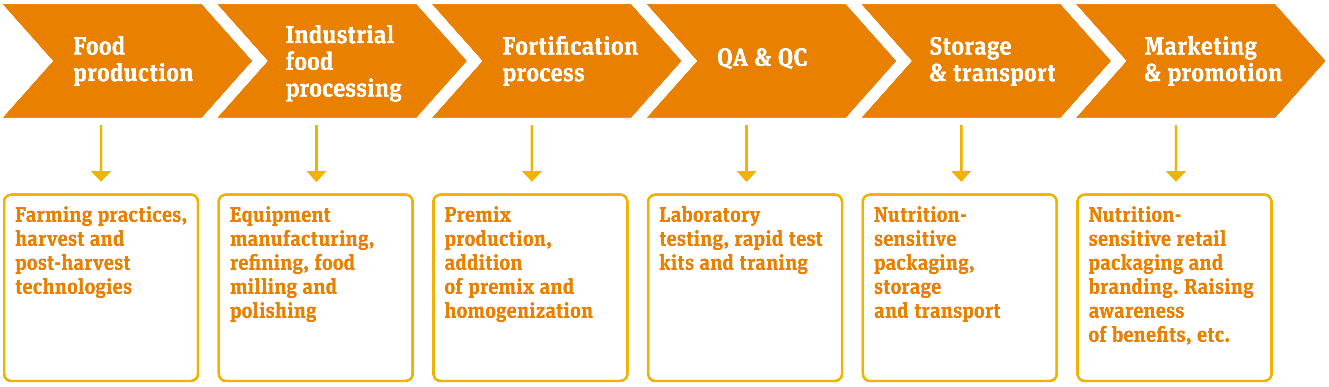
Figure 1 provides a simple "fortification value chain" which outlines: **1)** food production; **2)** industrial food processing; **3)** fortification processes; **4)** quality assurance and quality control; **5)** storage and transport; and **6)** marketing and promotion. Private-sector actors playing various roles in this value chain include: the food processing/rice milling industry; equipment manufacturers; manufacturers and suppliers of vitamins and minerals/multimicronutrient premixes; private food laboratories; and retail organizations (including cooperatives, where these exist).

Addressing the interests of the private sector in fortification

Fortification programs are most successful when driven by partnerships and trust between the public- and private-sector actors as outlined above, with a final public health objective. All actors should collaborate to create an enabling environment for rice fortification, with each stakeholder contributing their individual expertise and sphere of influence. This includes an appreciation and recognition of the important social benefits as well as the economic incentives required to deliver successful and sustainable fortification programming. The public health justifications for food fortification are widely accepted by the public sector, which has a key role to create the legislation and/or standards which support appropriate regulations for rice fortification and to establish clear rules which ensure the public interest.[2]

Because the private sector is the one undertaking the actual fortification processes, its motivation and interests require a special focus, including the need to see profitability as markets expand, to enhance brand value through improving nutritional content, and to help ensure fortified foods develop a healthy and productive labor force in low-income communities. This ongoing motivation is critical to the success of national, re-

FIGURE 1: Food fortification value chain



gional and global rice fortification efforts – during all phases of the project life cycle – including the "build" phase, when conducting rice landscape analyses to assess feasibility and when selecting points for blending and other critical milestones along the rice fortification value chain.

"There are various tools and guidelines available to help ensure public-private partnerships for nutrition and fortification are set up for success"

There are various tools and guidelines available to help ensure public-private partnerships for nutrition and fortification are set up for success so that these public and private interests are adequately addressed. These include: the 2009 Guidelines on Cooperation between the UN and the Business Sector;[3] the 2013 WFP Guidelines for Private-Sector Partnerships;[4] and the 2015 WHO Consultation Paper on Conflicts of Interest in Nutrition.[2] The Scaling up Nutrition Movement (SUN) hosts a Business Network which can help private-sector actors to become more engaged in the planning phases of fortification (see **Box 1**). It has produced a guide outlining how businesses can engage more effectively in nutrition programming.[5]

The private sector and delivery models for rice fortification

There are typically three different delivery options from which to choose when looking to roll out rice fortification programs, and each of these influences the role of the private sector: **1)** national, mandatory rice fortification; **2)** voluntary rice fortification, also referred to as commercial rice fortification; and **3)** distribution of fortified rice through social safety nets.

BOX 1: Opportunities to help engage the private sector in rice fortification

Today, 58 countries are actively engaged in the Scaling Up Nutrition (SUN) Movement – an effort which unites all stakeholders, including businesses, in a collective effort to improve nutrition.

SUN Countries in Latin America include Costa Rica, El Salvador, Guatemala, Haiti and Peru. In Colombia, the SUN Business Network (SBN) has partnered with a national business alliance for nutrition.

The role of the SBN is to engage companies, in partnership with the public sector and civil society, to create value for society through developing and producing nutritious products, and fostering demand for more nutritious foods, as well as delivering nutritious products and services to vulnerable populations at scale.

The network has seen rapidly growing engagement. Today, over 300 companies have joined the SBN and 23 SUN Countries have established, or are establishing, national SBNs. These national networks establish a consensus with government on where the private sector can best support national nutrition strategies, develop roadmaps for action and investment with business, and aim to establish partnerships and investments that will support business to mobilize greater action and investment in nutrition.

Of the 32 SUN Countries surveyed, fortification is one of the top two areas where governments are seeking greater engagement from business and are seeking advice and guidance on best practice through the SBN. There are opportunities to promote rice fortification with the private sector through the SBN, including:

- Work with the global SBN team to identify which SUN Countries would benefit from developing rice fortification programs – and establish a strategy to engage national stakeholders through the national SUN structures;
- Disseminate best practice to national SBNs through the SBN global team; and
- Use the SBN's national membership platforms to reach out to business.

The SBN is co-convened at the global level by the Global Alliance for Improved Nutrition (GAIN) and the UN World Food Programme (WFP).

> "Important considerations for selecting a delivery option include defining who covers the majority of the costs"

Important considerations for selecting a delivery option include defining who covers the majority of the costs. Start-up costs for equipment notwithstanding, the core cost of rice fortification is the production of the fortified kernels, of which the price of raw materials in the form of premix and rice flour (broken rice) are key cost components. It is important to consider how this core cost will be covered when selecting a delivery model (e.g., by government, donor, market/consumer or other means). For example, in voluntary fortification, the role of the private sector in ensuring that costs are covered by the market shifts considerably vis-à-vis demand creation and marketing in comparison to mandatory fortification or distribution through the social safety net. In addition to costs, the structure of the rice industry and the degree of centralization among rice processors and distribution channels are also important considerations when designing large-scale rice fortification programs and selecting a delivery model.

Delivery model 1: Mandatory fortification and the private sector

Mandatory fortification typically requires food producers to fortify both domestically produced and imported staple foods with specified micronutrients. Governments tend to mandate

BOX 2: The private sector in Costa Rica's successful mandatory rice fortification program

The Costa Rican mandatory rice fortification program has contributed to a reduction in folate deficiency and anemia among the population at large, and has led to reductions of neural tube birth defects and the infant mortality rate.

Background

Rice is the most important product in the Costa Rican food basket. This staple food is consumed in all three daily meals, and per capita consumption of rice is one of the highest in the region. The 1996 National Nutrition Survey showed a need for more essential vitamins and minerals in the country. It should be noted that rice is the only food product for which the price is regulated by the Government. Also because the rice industry is quite consolidated, mandatory rice fortification was more feasible.

Therefore, the Ministry of Health (MOH) decided it was vital that all rice in the country should be fortified. Through Executive Order No. 30031-S, the Presidency of the Republic and the MOH made the "Regulations for the Enrichment of Rice" official, which is used for all rice direct for human consumption in the country, whether of domestic production, donated or imported. Chapter II, Article 3, of that regulation states that "milled rice used for direct human consumption should be fortified with folic acid, vitamin B complex, vitamin E, selenium and zinc."

The development of this order was done in a step-wise fashion. The MOH had previous experience in the fortification of other foods, and the National Commission on Micronutrients (or CONAMI, the acronym in Spanish) was already established. The CONAMI, in conjunction with the National Association of Rice Producers (ANINSA), which represents 100% of rice mills in the country, held several deliberations to support the design of the fortification program. Technical and scientific studies were carried out early on between the public and private sector that facilitated decision-making. Following fortification trials, the cost of fortification was included in the fixed price of rice set by the government. The total extra cost of fortified rice is less than 1% of the cost of non-fortified rice.

The success of this mandatory rice fortification program was due to strong private-sector engagement from the start, in partnership with government.

Quality assurance or internal control of fortified rice is the responsibility of the producers and rice importers. Importers must show a certificate proving that the product complies with all specifications. Quality control and monitoring of rice fortification is the responsibility of the Ministry of Health at the final point of sale to the consumer.

fortification when micronutrient deficiencies are widespread, and when there is a suitable food vehicle that is consumed in sufficient quantities by most of the population.[6,7,8] Mandatory fortification requires government will and leadership to create the necessary legislation and monitoring system in order to enforce legislation.[9]

Experience shows that mandatory fortification has the greatest potential for health impact due to the fact that it creates necessary demand and can "level the playing field," providing assurance to rice millers that competitors are held to the same requirements, incur the same core costs, and will not be disadvantaged.[1,10] The degree of industry consolidation, size and modernization also contributes to the eventual coverage of the mandated program. Decentralized milling environments face both logistical and quality assurance challenges. The South and Central American regions, which have seen rapid centralization of the rice processing industry, arguably have a more conducive industry structure for implementing national-scale, mandatory rice fortification. Costa Rica has had much success in mandating rice fortification (**Box 2**).

Delivery model 2: Voluntary, market-driven rice fortification and the private sector

Given the barriers to mandatory fortification in many contexts, voluntary market-based approaches are often considered. Fortification is voluntary when the private food industry has the option to fortify its products. It is a business-orientated approach, with rice products marketed as "value-added" products. In countries like Colombia,[11] Brazil (**Box 3**) [12,13,14] and Dominican Republic, large rice millers have successfully pioneered rice fortification voluntarily, launching fortified rice products which improve consumer perception of a company's brand while providing better nutrition to consumers. However, due to slow build-up of consumer demand, especially among poorer populations, the potential for going to scale and influencing a population's micronutrient health may be limited. Voluntary approaches to rice fortification have not yet been systematically evaluated to see if health impact has been achieved.

In a voluntary commercial approach, an ecosystem comprising a category brand, a quality management system, social marketing and a governance framework are instrumental.

BOX 3: A voluntary approach to fortification in Brazil

"Magic rice," a nickname given by Mauricio de Sousa (creator of Mônica, the beloved Brazilian national cartoon character) or *arroz vitaminado* (meaning "vitamin rice") is fortified with vitamin B_1, folic acid, iron, and zinc. The result of more than 15 years of work, *arroz vitaminado* uses technology developed by PATH, funded by the Bill & Melinda Gates Foundation, and brought to market in partnership with GAIN through a pilot project which ended in 2015.

The aim was to develop a replicable model to scale up rice fortification through commercial channels. The project demonstrated the feasibility of introducing a fortified rice product to the market through a vertically integrated model and reached over 2.5 million consumers, 460,000 of whom were repeat consumers. Some of the lessons learned are discussed below.

Given the barriers to mandatory rice fortification, the pilot model was based on vertical integration, enabling a few upstream rice kernel producers to supply fortified kernels to numerous rice millers. Millers, who generally own the rice brands in Brazil, could then in turn blend the kernels with unfortified rice to market fortified rice to consumers..

Research showed that pricing was not a major barrier to commercializing rice, and should be driven by market forces. Fortified rice was on average 40% less expensive than the average rice of non-fortified rice, when including premium brands. Research showed that only one in five rice consumers has price as the top decision-driver. This environment allowed for the modestly higher costs brought by fortification to be absorbed by producers, retailers, and consumers.

Although the business model tested in this pilot offered an attractive business proposition to the fortified kernel supplier, it also created conflicts of interest for other millers, who felt discouraged to source from a competitor. Creating disincentives for other players to join the market risks generating a monopolistic situation and limits market growth. Program design should be based on careful microeconomic analysis and as far as possible avoid creating conditions that do not favor a competitive marketplace.

In Brazil, fortified rice has become a niche market that represents a single-digit percentage of the overall rice market and may demonstrate that a purely commercial model for fortified rice is not sufficient to reach meaningful scale and significant public health impact. Public-sector engagement is essential to de-risk fortification and level the playing field in rice fortification programs.

Smiling child, Guatemala 2012

These can help build trust in the positioning and messaging of fortified rice as beneficial to family health, establish a unique, common and visual identifier across fortified rice products represented by a logo, and boost the perceived value of the category, which would increase consumer willingness to pay the premiums for fortification.

> "The distribution of fortified rice through social safety nets is seen as an effective delivery option"

Delivery model 3: Social safety nets and the private sector

The distribution of fortified rice through social safety nets is seen as an effective delivery option, especially when mandatory national rice fortification is not feasible due to a fragmented rice milling landscape with many small-scale millers, and policy-makers want to ensure that more vulnerable populations are covered. Furthermore, social safety net programs can have a catalytic effect on voluntary rice fortification efforts. The deci-

BOX 4: Fortified rice for social safety nets in India and the private sector

In India, the public distribution of fortified rice has shown the promise of having a positive public health impact. After two local efficacy studies on the impact of fortified rice on micronutrient status in schoolchildren, a consortium of organizations conducted the first large-scale rice fortification trial in Odisha state, India. A baseline study among schoolchildren aged six to 14 years in Gajapati district (district in South Odisha) found that 19% of the sampled children were stunted (low height-for-age) and 14.5% were wasted (low weight-for-height). The survey revealed that 73% of the boys and 74% of the girls from primary school were affected by anemia.

After the baseline survey, a rice fortification trial started in April 2013 to evaluate the impact of a lunch meal with iron-fortified rice as part of the midday-meal program in Gajapati six times a week. The key objective of the project was to reduce the level of anemia in schoolchildren (by 5%), and establish a sustainable supply chain to fortify the rice in the school meal that can be scaled up in the state of Odisha.

The program reached over 100,000 children with iron-fortified rice. Part of the program was communication on the importance of a diverse diet, good sanitation and healthy nutrition (audience: schoolchildren, teachers, school management boards). The project was implemented by a consortium of stakeholders, including the Government of Odisha, WFP, PEACE (local NGO), SGS (laboratory), rice processing unit SSRM, and evaluating agency SAMBODHI. WFP provided technical support, managed the fortified rice supply chain, and had a coordinating role with the numerous stakeholders. Domestic production of the fortified kernels was a prerequisite of the government to move forward with the program. The NGO PATH was instrumental in ensuring extruded fortified kernels were produced domestically by transferring technical expertise and providing training to a large miller in Andhra Pradesh to produce the fortified kernels.

The set objectives were met, as the rice fortification overall program managed to reduce the prevalence of anemia by 20%, of which 6% could be attributed to the consumption of fortified rice as part of the midday meal.

Some of the challenges and insights included: **1)** at the start there was only one fortified-kernel producer, which was located in a different state – causing pipeline difficulties and near breaks; **2)** batch blending instead of continuous blending of the fortified kernels into the rice, which is labor-intensive and prone to quality issues due to shorter mixing times, caused by capacity limitations; and **3)** success of combining the program with nutritional awareness, including rice bags with messages on the importance of good nutrition that served as a school poster and a pot to grow vegetables in for a more diverse diet.

Because of the positive outcomes, Odisha state government decided to scale up the rice fortification to other districts and introduce multimicronutrient fortification. In addition, other states started projects to implement fortified rice in Public Distribution System (PDS) and Mid-Day Meal (MDM) programs.

In October 2016, the Food Safety and Standards Authority of India (FSSAI) published for the first time rice fortification guidelines for India. Furthermore, additional fortified kernel producers came on stream during 2016 that are interested in supplying the fortified kernels for the social safety net programs, as well as in launching branded fortified rice. All very promising developments after the start of introducing fortified rice successfully in the MDM program.

sion to fortify the rice distributed through social safety net programs is often made through a policy decision by government, UN agency, nongovernmental organization (NGO), or private entity, which normally also bears the costs of fortification, with zero or limited support from donor funding. **Box 4** provides an example on fortified rice for social safety nets in India.

Conclusion

While rice fortification has been an underutilized public health tool to date, the successes outlined in this paper provide important insights into how to ensure the role and interests of the private sector are leveraged appropriately vis-à-vis various delivery models, and that costs are appropriately absorbed. Mandatory rice fortification presents the best means of reaching a high coverage of population, but requires strong public-private partnerships and sustained commitments. Voluntary and market-driven approaches have seen traction, but strong consumer demand as well as government buy-in is crucial to achieve meaningful scale. Social safety net programs are an ideal platform for key partners to collaborate to bring fortified rice to vulnerable groups, and can build sufficient institutional demand to help ensure the financial viability of rice fortification. All three models require a firm commitment from the private sector and its engagement from start to finish of the project life cycle. Together, these insights can help the food and nutrition community build, improve and sustain rice fortification programs which achieve impact.

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Addressing Myths and Misconceptions about Rice Fortification

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Key Messages

- Rice fortification is safe.
- Where rice is the staple food and micronutrient deficiencies are widespread, rice fortification has great potential to significantly contribute to the reduction of micronutrient deficiencies. However, on its own it cannot eliminate all micronutrient deficiencies in a population: in the most vulnerable groups, e.g., pregnant and lactating women and preschool children, additional interventions such as supplementation are required.
- Micronutrient deficiencies affect all socioeconomic groups. Therefore, where micronutrient deficiencies are widespread, rice fortification benefits all socioeconomic strata of society.
- Rice fortification and biofortification differ as to the type, number and levels of micronutrients in rice, and as to when they are included in rice. In biofortification, the process of fortifying occurs during the crop production phase, or prior to the harvest. In rice fortification, the fortification is done post-harvest and can add more types and higher levels of micronutrients.
- When fortified with multiple micronutrients, white rice is more micronutrient-rich than brown, parboiled, or non-fortified white rice.
- With a few exceptions, any variety of rice can be fortified.
- Current technologies can produce fortified rice that tastes, smells and looks the same as non-fortified rice, and retains its nutrients when prepared using various cooking methods.

Introduction

Concerns, myths, and misconceptions exist regarding the benefits and safety of rice fortification. This paper addresses these concerns by presenting information from the global experience as well as evidence based on rice and wheat flour fortification.

> "The fortification of staple foods and condiments has been safely used for more than 90 years to help reduce micronutrient deficiencies"

Is rice fortification safe?

The fortification of staple foods and condiments – a strategy used for more than 90 years – has been proven safe and effective in significantly contributing to the reduction of micronutrient deficiencies. As with other food fortification, rice fortification is safe because the type and levels of micronutrients added are calculated based on the following:

- The recommended daily intake of specific micronutrients by age group and gender, as a person's age, gender and physiological status influences their daily nutrient requirements for healthy body functions
- The highest level of intake that is likely to pose no risks of adverse effects in an age and gender group, which is referred to as the tolerable upper intake level (UL). The fortification levels are chosen so that the UL is not exceeded when fortified food is consumed
- The level of specific micronutrients typically consumed by the target population
- The daily/regular quantity of rice consumed by the target population

This information is used to calculate the gap between the micronutrients consumed and the micronutrients required by specific groups. This gap is used to determine which micronutrients, and how much of the specific micronutrient, will be included in fortified rice. In other words, the level of micronutrients added is calculated such that the additional micronutrients provided in fortified rice will provide the greatest number of individuals in the target population with adequate intake, without causing intake above the UL by those who consume large quantities of the fortified rice. Fortified rice fills the micronutrient gap, without promoting excess intake.

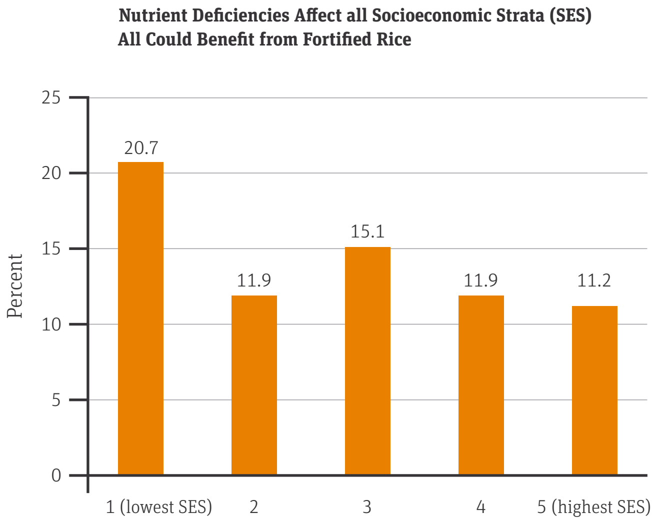
It is important to remember that:

- The type and levels of micronutrients are set in such a manner that even groups consuming large quantities of fortified rice will not exceed the UL. For example, in some countries, the typical adult consumes up to 400 or 500 g of rice per day. In this case, the micronutrients are added at a level that ensures that micronutrient intakes from all dietary sources are below the UL, taking a daily rice consumption of 400–500 g into consideration. Thus, the micronutrients consumed in fortified rice will be at a safe level.
- Specific population groups have higher micronutrient needs than others. For example, pregnant women are recommended to take iron/folate or multiple micronutrient supplements to meet their micronutrient requirements. This remains safe, and is recommended even when they are consuming fortified foods. This is because their micronutrient requirements are much higher than those of the average population. The same holds true for young children who also may be taking vitamin A or other micronutrient supplements. A young child also consumes much smaller quantities of rice than healthy adults in the same population. This, combined with their relatively high micronutrient needs, means that young children are not at risk of exceeding their UL with fortified rice.

Can rice fortification eliminate micronutrient deficiencies in the entire population?

Rice fortification can significantly contribute to the reduction of micronutrient deficiencies. For safety reasons, the fortification levels are calculated such that the additional micronutrients provided in fortified rice will provide the greatest number of individuals in the target population with adequate intake, without causing excessive intake. On its own, this level of fortification cannot eliminate all micronutrient deficiencies among all segments of the population. For example, a pregnant woman has significantly higher micronutrient needs than a man of the same age. Fortified rice can contribute to meeting the needs of pregnant women, but cannot fully meet their needs. Children under the age of two years also have relatively high micronutrient needs to support their growth and development. However, they can only consume small quantities of food in comparison to adults, so the additional micronutrients received by eating fortified rice will not be sufficient to fill their gap in micronutrient intake. Therefore other simultaneous micronutrient interventions are necessary to increase the micronutrient intake of these target populations. For more information on addressing nutrition objectives, please refer to the contribution by Rudert et al (p. 193).

FIGURE 1: Percentage of non-pregnant Vietnamese women (15–49 years) with iron deficiency, by socioeconomic group.



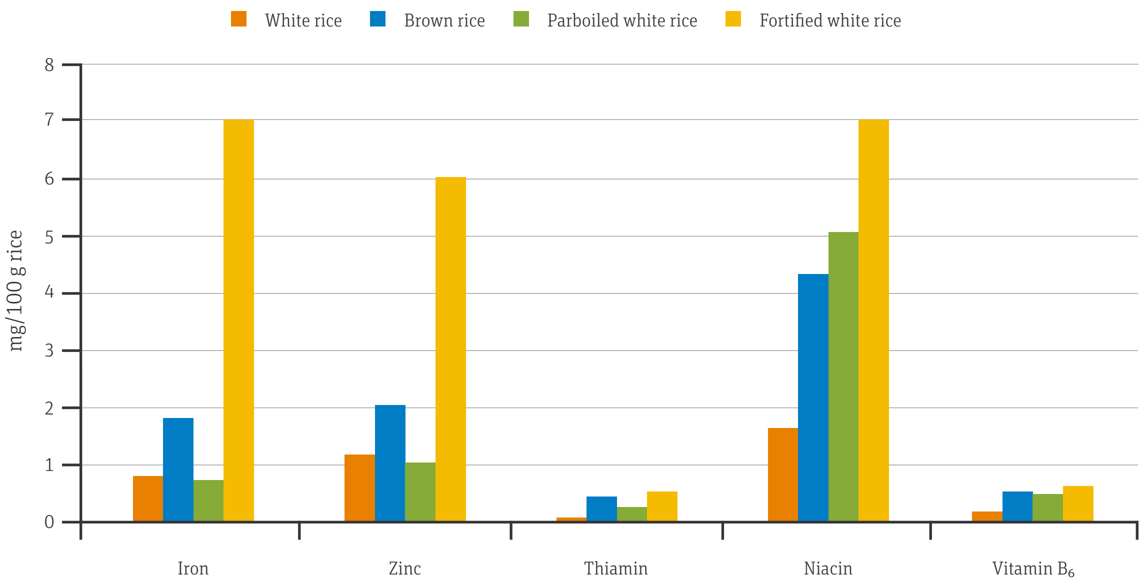
Adapted from[1]

> "Fortified rice can help meet the needs of pregnant women and of young children, but cannot fully meet their needs"

Is fortified rice only needed by low-income groups?

Although micronutrient deficiencies are more prevalent among lower socioeconomic groups, deficiencies also occur in higher-income groups, urban populations, obese individuals, and individuals with higher-than-average education. For example, as shown in the 2000 Vietnamese National Nutrition Survey (see **Figure 1**), iron deficiency was highest among women from the lowest socioeconomic group (20.7%). However, at least 11% of women from higher socioeconomic groups were also iron deficient, even in the highest income group.[1] This demonstrates that fortifying rice with iron can benefit all strata of society who consume rice.

FIGURE 2: Profile of select micronutrients in white rice, brown rice, parboiled white rice, and fortified white rice.[4]



What is the difference between fortified and biofortified rice?

Rice fortification and biofortification are two different approaches to make rice more nutritious. They can safely coexist as part of a strategy to improve micronutrient health. The difference lies in when and how micronutrients are added, and the type, number and level of micronutrients that can be incorporated.[2]

In rice fortification, micronutrients are added after the rice has been harvested. For example, folic acid, niacin, vitamins B_1 (thiamin), B_6 (pyridoxine) B_{12} (cobalamin), A (retinol), D (cholecalciferol), E (tocopherol), iron, zinc and selenium can be added without changing the appearance of the rice. For additional information, please refer to the contributions by de Pee et al (p. 143), Montgomery et al (p. 159) and Rudert et al (p. 193).

Biofortification increases the micronutrient content through breeding or genetic modification (GM). Therefore it occurs *before* harvesting the crop. An example of biofortification is Golden Rice, which expresses β-carotene.[3] In practice, a limited number of nutrients are increased in biofortified rice varieties at any one time, and research is ongoing to increase their levels. Currently, only non-GM rice cultivars with higher iron or zinc levels are available. Genetically modified Golden Rice containing provitamin A has not been released on the market.

In addition, the levels of nutrients that are added to rice can be much higher with fortification than with biofortification. However, once a rice variety is biofortified, no additional processes are needed after harvesting to increase nutrient levels.

Why not encourage consumption of brown rice or parboiled rice instead of fortified white rice?

White rice is widely consumed, and when fortified, can have a significantly higher micronutrient content than non-fortified rice, including brown or parboiled rice. Therefore, there is a greater potential to improve micronutrient health by fortifying white rice than from increasing consumption of brown or parboiled rice.

> "When fortified, white rice can have a significantly higher micronutrient content than non-fortified brown or parboiled rice"

Figure 2 shows the micronutrient content (iron, zinc, thiamin, niacin and vitamin B_6) for non-fortified rice (white, brown and parboiled) and fortified white rice.[4] The content of folate and vitamins A and B_{12} are not shown because they are absent or negligible in all types of rice except fortified rice. The data demonstrates three points:

1. Milling removes much of rice's naturally occurring nutrients
2. Parboiling retains a significant level of some nutrients
3. Brown rice is relatively iron- and zinc-rich compared to non-fortified white rice

While the nutrient content of fortified rice is dependent on the amounts added, fortified rice has the potential to offer much higher levels of key nutrients such as iron, zinc, vitamin A, folic acid and vitamin B_{12}.

In addition, the consumption of fortified white rice does not require a change in existing behaviors, as would be the case if consumption of brown or parboiled rice were to be increased. While there is little data on brown rice consumption in Asian countries, the 2009 US National Health and Nutrition Survey[5] found that, after years of promotion, only 2.9% of children and 7.7% of adults consumed the recommended daily level of at least three whole grain ounce equivalents (which includes brown rice). This finding is in line with lessons learned from wheat flour and salt fortification to the effect that communication alone without additional behavior change activities does not increase consumption of a specific food.

> "The acceptability of fortified rice depends on the fortification technology, the type and level of nutrients, and consumer preferences"

Can any variety of rice be fortified?

The rice fortification technology of dusting can be used to fortify all varieties of rice, although this technology is not recommended. For coating and extrusion, most varieties of rice can be fortified; however, this will require tailoring of fortified kernels accordingly. For more information on rice fortification technology, please refer to the contribution by Montgomery et al (p. 159).

Is fortified rice acceptable to consumers?

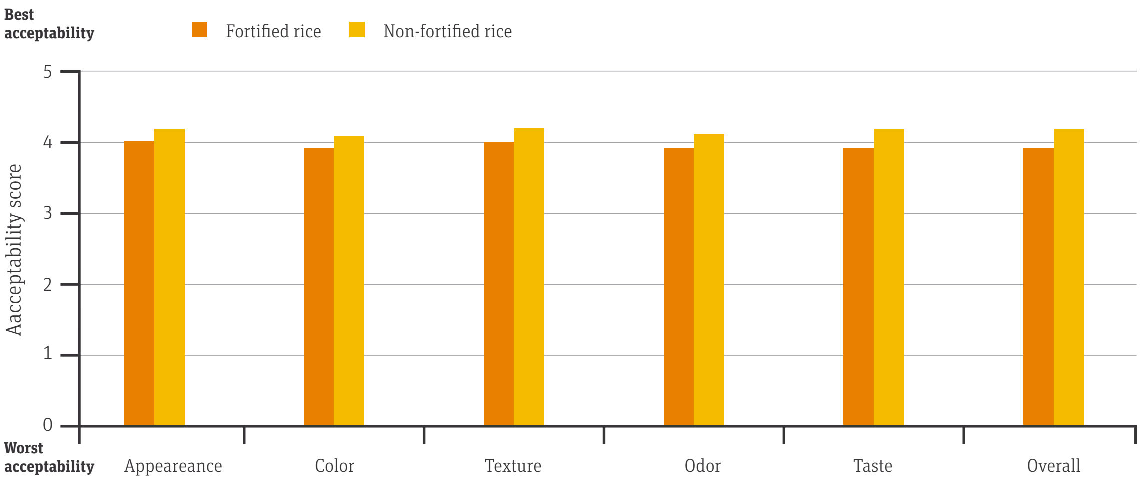
The acceptability of fortified rice depends on the fortification technology, the type and levels of nutrients added, and consumer preferences. All rice fortification technologies aim to make fortified rice taste, smell, and look the same as non-fortified rice.

A recent study that compared rice fortified using extrusion technology with non-fortified rice evaluated six sensory parameters (appearance, color, texture, odor, taste, and overall acceptability) among Indian children 8–11 years of age.[6] The children ranked each sample with a score of 1 (worst) to 5 (best). As shown in **Figure 3**, the fortified and non-fortified rice were statistically indistinguishable on all six sensory parameters. In addition, all sensory parameters were rated over 4 points, suggesting strong acceptability for both types of rice. This study shows that consumers perceive fortified rice to taste, look, and smell similar to non-fortified rice.

Are the nutrients in fortified rice retained after preparation and cooking?

When produced using extrusion or rinse-resistant coating technologies, fortified rice will retain nutrients through various preparation and cooking conditions, including washing and cooking in excessive water that is later discarded. The micronutrients in the fortified kernels produced with extrusion technology are evenly distributed throughout the kernels. Therefore, the nutrients are adequately sealed and adequately retained through preparation and cooking. However, when fortified rice is produced using dusting or coating that is not rinse-resistant, nutrients will be lost if the rice is washed prior to cooking. There is ongoing additional research in this area to further identify potential differences in nutrient retention between different rice preparation and cooking methods and fortification technologies.

FIGURE 3: Acceptability scores for fortified and non-fortified rice among Indian children aged 8–11 years.



Adapted from[6]

An indigenous mother carrying her baby, Guatemala 2012

"Fortified rice is acceptable to consumers, as virtually any variety of rice can be fortified"

Conclusion

Fortified rice is safe and acceptable to consumers. Fortification levels are set such that the additional micronutrients consumed will provide the greatest number of individuals in the target population with adequate intake, without causing excessive intake. Fortified rice is acceptable to consumers, as virtually any variety of rice can be fortified and, if properly produced, will taste, smell and look the same as non-fortified rice. Fortified white rice may be more readily acceptable to consumers than less micronutrient-rich types of non-fortified rice, such as brown or parboiled rice. However, fortified rice should be part of a larger micronutrient intervention strategy, as population groups with higher nutrient needs, such as pregnant and lactating women, will require additional interventions to meet their micronutrient needs.

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Linking Rice Fortification Opportunities with Nutrition Objectives

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Key Messages

- Linking rice fortification with nutrition objectives requires the identification of groups who are most at risk of micronutrient deficiencies, the groups who can most benefit from rice fortification, and the most appropriate delivery option to reach these vulnerable groups.
- In order to determine the potential impact of rice fortification, the population's micronutrient status should be assessed through a combination of available data on their biochemical micronutrient deficiency status, nutrient intake, and other proxy indicators. There is no need to conduct additional micronutrient surveys where this information is available.
- Mandatory fortification has the greatest potential to make a public health impact when it reaches the whole population. When this is not feasible, distribution of fortified rice through social safety net programs is an alternative.
- Social safety nets typically target the same population groups that can benefit most from rice fortification (e.g., schoolchildren and lower socio-economic groups). Voluntary fortification is likely to benefit higher income groups only.
- Rice fortification cannot completely fill the micronutrient gap for groups with high micronutrient needs, such as pregnant and lactating women and young children. Additional targeted interventions remain necessary, such as iron/folate supplementation for pregnant women or micronutrient powders for young children.

Introduction

To determine the potential impact and the most appropriate delivery channel for fortified rice, it is essential to understand the population's micronutrient status, existing programs to improve micronutrient status, and the extent to which rice fortification can contribute to the micronutrient intake of the population. This article describes the process of identifying the type and level of micronutrient deficiencies in the population and the groups that are most affected. It also explains how the different delivery options may help to improve micronutrient status among identified vulnerable groups.

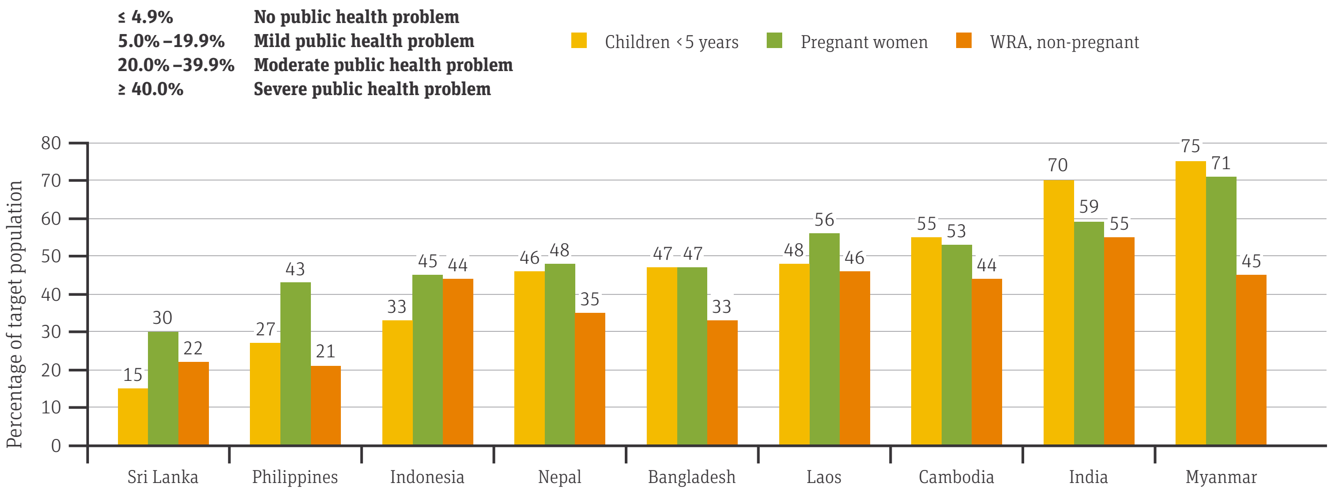
Importance of understanding micronutrient status

An analysis of the micronutrient deficiency situation is the first step in estimating the potential of fortified rice to improve the micronutrient status of the population.

As with all food fortification, rice fortification aims to increase a population's intake of specific micronutrients in order to reduce the proportion of that population which is at risk of micronutrient deficiencies. At the same time, fortification levels need to be set so that those who consume larger amounts of the food vehicle are unlikely to exceed the so-called tolerable upper intake level (UL). In other words, the vitamins and/or minerals added to rice should make a significant contribution to the micronutrient intake of the general population while not providing too much to individuals who consume relatively large amounts of rice. For additional information on safe micronutrient fortification of rice, please refer to the contributions of de Pee et al (p. 143), Pachón et al (p. 188) and Bruins in *Sight and Life* 1/2015, pp. 45–50.

> "A combination of available data and proxy indicators is sufficient for estimating the burden of micronutrient deficiencies"

FIGURE 1: Prevalence of anemia in three vulerable groups, for nine Asian countries.[2]



To gain a comprehensive understanding of a population's micronutrient status, it is recommended to examine data from multiple sources and methods, and where possible disaggregate by population group using factors such as socioeconomic status and geographic location, in addition to age and gender. This segmentation helps identify the target groups who can most benefit from rice fortification. The three main sources of information for obtaining a picture of the micronutrient status of a population are:

1) Micronutrient deficiency surveys, using biochemical data
2) Dietary intake of micronutrients, usually with 24-hour recall surveys
3) Proxy indicators, such as prevalence of anemia, stunting, neural tube defects, dietary diversity, infant and young child feeding practices, food security, and sanitation

It is important to emphasize that having complete micronutrient and nutrient intake data is NOT a prerequisite for fortification initiatives. A combination of available data and proxy indicators is sufficient for estimating the burden of micronutrient deficiencies.

"Multiple micronutrient deficiencies tend to coexist in low- and middle-income countries"

Multiple micronutrient deficiencies tend to coexist in low- and middle-income countries. The most common ones are iron, iodine, and vitamin A. These can be estimated using biochemical data. Zinc deficiency also makes a substantial contribution to the global burden of disease. Black et al, in the landmark 2013 Lancet Maternal and Child Nutrition series, used an analysis of national diets to estimate that 17% of the world's population is at risk of zinc deficiency.[1] This method was used as there is little biochemical data on zinc deficiency. These detectable deficiencies may also coexist with other deficiencies that are harder to detect, such as vitamin B_{12}, folic acid or vitamin D. For additional information on the global burden of micronutrient deficiencies, please refer to **Figure 1** in the contribution by Milani et al (p. 137).

Micronutrient deficiency surveys can estimate a population's micronutrient status using biomarkers such as plasma retinol or retinol binding protein (RBP) for vitamin A, or ferritin to estimate iron. However, validated biomarkers do not exist for all micronutrients, and the interpretation of the results can be complex. In addition, logistics, sample collection and storage of samples may be complex. Although micronutrient deficiencies primarily affect the poorest and rural populations, other socioeconomic strata and urban populations may also be affected. For additional information, please refer to **Figure 1** in the contribution by Pachón et al (p. 188).

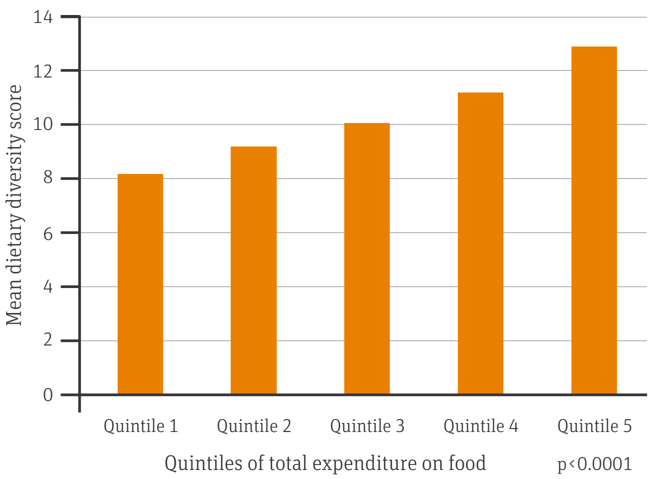
Dietary intake data

Data on foods commonly consumed by the population can supplement biochemical and clinical evidence of micronutrient deficiencies. Such data can help to identify which micronutrients are most likely to be insufficient, which population groups have insufficient diets and which areas of the country are most affected, using food composition tables indicating the micronutrient content of the foods.

Use of proxy indicators

When nutrient intake data is not available, as is often the case in low-income countries, proxy indicators can be used to esti-

FIGURE 2: Mean dietary diversity score by quintiles of total expenditure on food



Adapted from[7]

mate the population's risk of micronutrient deficiencies. Anemia, stunting, dietary diversity and neural tube defects are most often used as proxy indicators. Additional indicators include infant and young children feeding, sanitation, and other health and food security indicators.

Anemia, commonly used as a proxy indicator for iron deficiency, has multiple causes, beyond inadequate iron or other micronutrient intake (e.g., vitamin A, folic acid, vitamin B_{12}). Anemia is most prevalent in children under five, pregnant women, and women of reproductive age. Although there is significant variation by country, it is estimated that globally only half of the anemia is caused by iron deficiency.[2] Non-nutritional causes of anemia include hookworm infestation, malaria, other infections, and red blood cell disorders such as thalassemia. **Figure 1** shows the high prevalence of anemia across nine Asian countries.

Stunting for children under five years of age can also be used as a proxy indicator for micronutrient deficiencies. Countries where stunting is of significant public health concern also experience significant micronutrient deficiencies, as the two public health problems share many of the same causes,[3] such as inadequate nutrient intake and illness. Significant disparities exist in stunting prevalence, with children in the lowest income percentile up to three times more likely to be stunted compared to children in the highest income percentile. Rural children are up to twice as likely to be stunted compared to urban children.[4] The disparities in stunting prevalence often mirror disparities in micronutrient status and household income levels. Nevertheless, in many Asian countries there are also substantial stunting rates in high-income and urban populations.

Dietary diversity is commonly used as a proxy indicator for risk of micronutrient deficiencies, as a lack of dietary diversity often results in micronutrient deficiencies. Diets lacking in diversity may have a high intake of plant-source foods and a low intake of animal-source foods, which are associated with deficiencies of key micronutrients. Cereals, roots and tubers have very low micronutrient content and/or low bioavailability (especially after milling). Monotonous diets based on these staples typically provide only a small proportion of the daily requirements for most vitamins and minerals. Fat intake, which aids absorption of fat-soluble vitamins, is also often very low with diets of poor diversity.

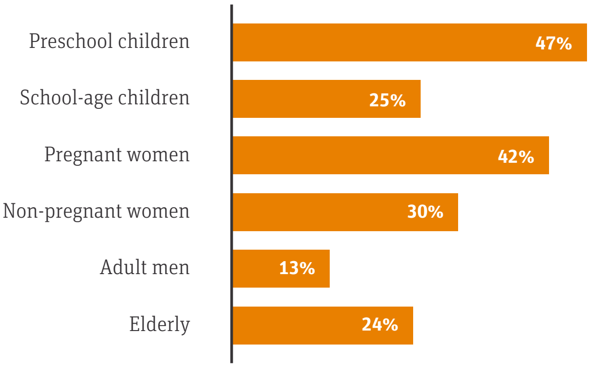
Animal-source foods are rich sources of protein (essential amino acids), energy, and micronutrients, including iron, preformed vitamin A, vitamin B_{12}, riboflavin, calcium, phosphorus and zinc.[5] Vulnerable groups in populations with a low intake of animal-source foods are more likely to have deficiencies in some or all of these nutrients.[5] Animal-source foods also fill multiple micronutrient gaps with smaller volumes of intake than plant-source foods. For example, to meet the daily requirements for energy, iron, or zinc, a child would need to consume 1.7–2.0 kg of maize and beans in one day. In addition, animal-source foods do not have the anti-nutritional factors that are present in plant-source foods (pulses, grains, and legumes). Anti-nutrients, or inhibitors, are natural compounds that impair the digestibility and absorption of essential nutrients. One common plant-based inhibitor is phytate, which inhibits the absorption of minerals, especially iron and zinc.[5] Plant-based foods are often a good source of vitamin B_6, niacin and thiamin. However polishing rice markedly reduces its micronutrient content.[6]

Wealthier households tend to have more diverse diets. As shown in **Figure 2**, a study in Bangladesh found a strong correlation between household dietary diversity and socioeconomic status and expenditure on food.

Neural tube defects (NTDs) can be used as a proxy indicator for folic acid deficiency.[8] NTDs, including spina bifida, occur when part of the neural tube, which forms the spine, spinal cord, skull and brain, fails to close between 21 and 28 days after conception – before women typically realize they are pregnant. Many children affected by neural tube defects have multiple lifelong disabilities. Women with low folate intake before and during early pregnancy are at increased risk of having babies with NTDs. It is recommended that all women of reproductive age should receive folic acid daily, which can be added to their diet through fortification or supplementation.

Other proxy indicators that can be used as indicators of risk of micronutrient deficiencies are high infection prevalence, low health service access/utilization, poor sanitation, hygiene and water quality, high food insecurity, proportion of household food expenditure on e.g., non-grain or animal-source foods, in-

FIGURE 3: Prevalence of anemia in different age groups.[2]



WHO 2008: Worldwide prevalence of anemia

adequate breastfeeding and infant and young child feeding and caring practices, etc.

Assessing the burden of micronutrient deficiencies

Although rice fortification can benefit a wide range of population groups, it is important to assess which population groups have the highest risk of micronutrient deficiency or inadequate intakes, and why. **Figure 3** shows the estimated prevalence of anemia across different population groups. The highest prevalence is estimated for preschool children with almost half of the children estimated to be anemic. In comparison, only 13% of adult men are estimated to be anemic.

> "It is important to assess which population groups have the highest risk of micronutrient deficiency, and why"

Several vulnerable groups are most likely to be affected by micronutrient deficiencies:

- **Girls and women of reproductive age** are biologically more vulnerable, especially to iron deficiency, as they experience iron loss due to menstruation.
- **Pregnant and lactating women** have greater micronutrient requirements to support growth and breastfeeding.
- **Infants and young children** have greater micronutrient requirements due to rapid growth. Their relatively small stomach size also limits their intake of foods. Therefore, their foods should be more nutrient dense than food that is consumed by older age groups.
- **Adolescents** have increased micronutrient requirements due to growth spurts.
- **Lower socioeconomic groups** tend to have a higher prevalence of deficiencies compared to higher socioeconomic groups. Typically, the diets of lower socioeconomic groups lack diversity and are primarily based on cereals, roots and tubers, with limited animal-source foods, fats and fruits and vegetables. Although the diets of poorer populations tend to be more micronutrient-deficient, the transition to energy-dense but micronutrient-poor diets with a high proportion of processed foods also puts higher-income groups at risk of micronutrient deficiencies.
- **Populations affected by emergency**, due to poor dietary diversity (mitigated to some extent when they receive fortified foods).
- **Groups marginalized** as a result of geography, ethnicity or religion.

Potential to benefit from food fortification varies across life cycle

As a population-based intervention, rice fortification must benefit those at risk of deficiencies, while remaining safe for the members of the general population that consume the most rice. To calculate the potential benefit that rice fortification can provide, the following must be assessed:

- The existing need for micronutrients, defined by the likely dietary gaps.
- The quantity of fortifiable food consumed, defined as the total amount of food consumed and the types and sources of foods that can be fortified.
- The level of fortification, where the aim is to provide enough micronutrient to reach the estimated average requirement (EAR) of adult men or women (which is approximately 70% of the recommended nutrient intake) from the fortified food, using the typical amount of the food that is consumed by adult men and women to determine the content per 100 g. For more information on calculating levels of micronutrients, please refer to the contribution by de Pee et al (p. 143).

Rice fortification is one component of an integrated approach to address micronutrient deficiencies, including micronutrient supplementation (for specific target groups), promotion of dietary diversification, social protection schemes, and disease control. The potential of rice fortification to address micronutrient deficiencies varies across the life cycle. As shown in **Figure 4**, the potential for benefit from rice fortification depends on the needs of the target group, the amount of fortified rice

FIGURE 4: Potential to benefit from food fortification across the life cycle

	Pregnancy	Lactating mother	6–23 mo	2–5 years	5–18 years	WRA (15–49 years)	Adult men	Elderly
Micro-nutrient need	very high	very high	very high	high	moderate to high	moderate to high	low to moderate	moderate to high
Amount of food eaten	moderate	moderate	low	low, increasing with age	increases with age	moderate	high	moderate
Potential to benefit	high	high	low	low, increasing with age	increases with age	high	high	high
Potential to fully meet need	**low**	**low**	**no**	**low, increasing with age**	increases with age	high	high	high

the group typically consumes, the group's potential to benefit from fortified rice (dietary gap), and the potential of the fortified rice to meet the target group's micronutrient needs (filling the gap).

As shown in **Figure 4**, pregnant and lactating women have high micronutrient needs. They also have a high potential to benefit from rice fortification, because they consume a substantial amount of rice. However, despite making a good contribution, fortified rice will not be able to provide enough micronutrients to fully meet their needs. Children aged 6–23 months also have very high micronutrient needs. However, given the small quantity of rice they consume, fortified rice has a low potential to meet their micronutrient needs.

FIGURE 5: Potential public health benefit of different delivery options for fortified rice among vulnerable socioeconomic groups

Delivery option	Low income	High income	Rural	Urban
Voluntary	**low**	high	**low**	high
Mandatory	high	high	high	high
Social safety nets	high	**low**	high	high

"Rice fortification should be one component of an integrated approach to address micronutrient deficiencies"

Public health impact of rice fortification depends on choice of delivery option

The potential public health impact of rice fortification for specific socioeconomic population groups is dependent upon the choice of delivery options (**Figure 5**).

Mandatory fortification is generally recognized as the most effective and sustainable option. It provides more equitable access, has the potential to reach the majority of the population, and significantly helps lower the national prevalence of micronutrient deficiencies. The most vulnerable socioeconomic groups will benefit.

Voluntary fortification has significantly lower potential to reach the most vulnerable groups, such as lower socioeconomic groups and rural populations. In this market-driven approach, these groups may not be able to afford or access branded fortified rice due to higher pricing. However, voluntary fortification can help meet the nutrient requirements of some segments of the population, typically high-income groups. Experience so far has indicated that coverage remains rather low, even with high-income groups. As such, the public health impact of voluntary fortification is limited.

The distribution of fortified rice through social safety nets has great potential to reach those most at risk for micro-

A mother carrying her baby, Colombia 2013

nutrient deficiencies. However, its contribution to reducing micronutrient deficiencies among the wider population depends on the proportion of the population that is reached by the social safety net.

For more information on delivery options, please refer to the contribution by Codling et al (p. 170).

Conclusion

Rice fortification has the potential to contribute to the reduction of micronutrient deficiencies and positively impact public health. While all population groups may be micronutrient-deficient, the magnitude varies between groups. Additional interventions specifically targeted towards those with the highest micronutrient needs, such as pregnant and lactating women and preschool children, remain necessary.

Linking rice fortification with nutrition objectives requires the identification of groups which are most at risk of micronutrient deficiencies, the groups that will benefit the most from rice fortification, and the most appropriate delivery option to reach identified target groups. Mandatory fortification offers the greatest potential for achieving a public health impact. The fortification of rice distributed through social safety net programs provides an opportunity to reach vulnerable groups when mandatory fortification is not feasible.

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Landscape Analysis for Rice Fortification

Summary of results

Introduction

To create viable, sustainable and cost-effective rice fortification programs, key factors such as rice industry structure, standing policies and regulations and political will, among others, must be identified and studied before a formal process of development and implementation is initiated. That is why carrying out a Landscape Analysis for Rice Fortification should be the first step in introducing, implementing and carrying out a fortification strategy that considers all the key aspects for decision-making by the government, the private sector, and civil society.

A situation analysis should, at minimum, determine the most viable delivery channels; how to integrate the fortification steps into the rice supply chain; how to create, adapt or improve public policies and existing regulatory frameworks; the estimated costs relative to the strategy's public health impact; and the key stakeholders to be included in the process.

With the objective of informing the group work carried out during the *Scaling Up Rice Fortification in Latin America and the Caribbean* (see page 212 for full workshop report), a Landscape Analyses was commissioned for each participating country. Each profile considered and sought to include all the key components recommended by Yusufali et al in the series on rice fortification in Asia, which precedes this supplement.[1]

Overall, the profiles provide a wealth of information on the situation for rice fortification in the region, but they also have their limitations. The multiple information gaps at the country level and the lack of precision or updating of the data is evident. None of the countries have all the necessary information recommended first hand. It is also important to note that national percentages sometimes hide a much more worrying nutritional reality among the most vulnerable populations.

Despite the above constraints, data collection – commissioned by the Regional Office of the World Food Programme (WFP) – lays the foundation for initiating country-level discussions for, and building on, rice fortification.

The following is a summary of some key data for each country; complete profiles can be requested through: **rebrand.ly/Country-Profiles**

Children waiting for their lunch, Choco Colombia 2004

Colombia

Nutrition situation

Chronic malnutrition in children under 5 years	13.2%
Anemia	**By age group (%)**
6–11 months	59.7
6–59 months	27.5
Women of reproductive age	17.9
Vitamin A deficiency (1–4 years of age)	24.3%
Zinc deficiency (1–4 years of age)	43.3%

Source: Colombian Family Welfare Institute. National Survey of Nutrition Status in Colombia (ENSIN) 2010. Bogota. 2011.

Government/public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Salt › *Fortificants:* Iodine, fluorine
	Wheat flour › *Fortificants:* Vitamin B_1, B_2, B_3, iron
Fortification of specific foods	Bienestarina[a] › *Fortificants:* Vitamins A, D, C, B_1, B_2, B_3, B_6, B_{12}, folic acid
	› *Minerals:* Iron, zinc, calcium, copper, n-3 fatty acids
	› *Population:* Children 6–36 months
	Fortified milk and biscuits › *Fortificants:* Folic acid, iron, zinc
	› *Population:* Children 6–59 months
Supplementation programs	Micronutrient powders › *Fortificants:* (UNICEF/WFP 15-micronutrient
	formula) vitamins A, D, E, C, B_1, B_2, B_3, B_6, B_{12}, folic acid
	› *Minerals*: Iron, zinc, copper, selenium, iodine
	› *Population:* Children 6–59 months

[a] Fortified complementary food

Fortified foods in the commercial market

› Bread	› Margarine
› Pastas	› Vegetable oils
› Crackers	› Fruit juice
› Rice *	› Drinks with juice
› Pasteurized milk	› Instant drinks
› Powdered milk	› Drinks for athletes
› Milk drinks	› Dietary foods
› Yogurt	› Breakfast cereals
› Yogurt drinks	› Vegetable mixes
› Milk substitute drinks	› High protein foods
› Child formula	› Nutrition bars

* Currently about 35% of rice consumed in the country is voluntarily fortified by industry using spray technology, of which the micronutrient retention, stability and efficiency are not known.

Social protection programs that deliver rice

None

Legislative framework for rice fortification

None

Rice consumption patterns

% who consume it daily: **96.0%**

Consumption per person per day (in g): **106**

Annual per capita consumption (in kg): **40**

Characteristics of the rice industry

Rice production (in tons): **2,091,517**

Cultivation yield (t/ha): **4.16–5.7**

Number of mills: **83**

Area planted with rice (ha): **478,878**

Imports (t)*: **680,013**

Source

Camilo Rozo, MSc, PhD, CFS, Landscape Analysis for Rice Fortification: Colombia. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

* Contraband rice is a challenge in Colombia. It is estimated that it represents 24% of the rice consumed.

Cuba

Nutrition situation

Chronic malnutrition in children under 5 years	–
Anemia	**By age group (%)**
6 –11 months	41.4
6 –59 months	29.5
Pregnant women	21.6
Pregnant women	8.5 %
Zinc deficiency (1–4 years of age)	–

Source: Food and Nutrition Surveillance System (SISVAN).

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Salt › *Fortificants:* Iodine
	Wheat flour › *Fortificants*: Vitamins B_1, B_2, B_3, B_6,, B_{12}, folic acid, iron
Fortification of specific foods	Powdered milk › *Fortificants:* Iron and zinc for every 1000 mL
	› *Population:* Children under 7 years of age
	Fruit puree › *Fortificants:* Iron, ascorbic acid for every 100 g
	› *Population:* Children 6 –36 months
	Soy yogurt › *Fortificants:* Calcium | *Population:* Children 7–13 years
	Fortified soy milk › *Fortificants:* Vitamin A
	› *Population:* Older adults over 65 years of age
	Materlac [a] › *Fortificants:* Vitamins A, D, E and B-complex, iron, zinc, copper
	magnesium, manganese, calcium, phosphorus, sodium and potassium
	› *Population:* Pregnant women at risk of malnutrition
	Lactosan[b] › *Fortificants:* Vitamins A, D
	› *Population:* Breast milk substitute
Supplementation programs	Prenatal supplement › *Content:* Iron, folic acid, vitamin A, vitamin C
	› *Population:* All pregnant women
	Iron and folic acid supplement (Mufer)
	› *Content:* Iron, folic acid
	› *Population:* Pregnant women at risk of malnutrition
	Iron drops (Forfer) › *Content:* Iron, folic acid
	› *Population:* Children 6–60 months

[a] Fortified cereal, [b] Fortified cereal/complementary food

Fortified foods in the commercial market

Information not available

Social protection programs that deliver rice

3.18 kg /month of subsidized rice are distributed to the entire population in the family basket and also through social safety nets with different consumption standards.

Legislative framework for rice fortification

None

Rice consumption patterns

% who consume it daily: : **–**

Consumption per person per day (in g): : **–**

Annual per capita consumption (kg): **70**

Characteristics of the rice industry

Rice production (in tons): **–**

Cultivation yield (t/ha): **3.2**

Number of mills: **34**

Area planted with rice (ha): **120,000**

Imports: **50%** of the rice for human consumption

Source: Armando Rodríguez, Landscape Analysis for Rice Fortification: Cuba. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean.

Link to full profile: **rebrand.ly/Country-Profiles**

Guatemala

Nutrition situation

Chronic malnutrition in children under 5 years	46.5%
Iron deficiency	**By age group (%)**
6 –11 months	80.1
6 –59 months	18.6
Women of reproductive age	14.3
Pregnant women	31.9
Vitamin A deficiency (children under 5)	0.3
Zinc deficiency (children under 5)	25–38.6%

Source: MSPAS. National Micronutrient Survey 2009–2010 (ENMICRON). Guatemala; 2012

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Salt › *Fortificants:* Iodine
	Wheat flour › *Fortificants:* Iron, vitamins B_1, B_2, B_3, folic acid
	Corn flour › *Fortificants:* Vitamins B_1, B_2, B_3, B_{12}, folic acid, iron, zinc
	Sugar › Vitamin A
Fortification of specific foods	Vitacereal[a] › *Fortificants:* Vitamins A, C, D, E, B_1, B_2, B_3, B_5, B_6, B_7, B_{12}, folic acid, iron, zinc, iodine, calcium › *Population:* Pregnant women, nursing mothers and children aged between 6 and 35 months living in municipalities with malnutrition rates above 65%
	Super Cereal plus (My little food)[b] › *Fortificants:* Vitamins A, C, D, E, B_1, B_2, B_3, B_5, B_6, B_7, B_{12}, folic acid, iron, zinc, iodine, calcium, potassium, phosphorus, magnesium, copper, manganese, selenium

Fortification of specific foods	› *Population:* Children 0–2 years old, pregnant and lactating women in the districts of Totonicapán, Sololá and Chimaltenango
	Incaparina[c] › *Fortificants:* Vitamins A, D, K, B_1, B_2, B_3, B_{12}, folic acid, iron, zinc, iodine, calcium
	Bienestarina[d] › *Fortificants:* Vitamins A, B_1, B_2, B_3, B_{12}, folic acid, iron, zinc, calcium
	Peanut +[e] › *Fortificants:* Vitamins A, C, D, E, B_1, B_2, B_5, B_6, B_{12}, folic acid, iron, zinc, iodine, calcium, potassium, phosphorus, magnesium, copper, manganese, selenium
Supplementation programs	Iron › *Population:* Children 6 months to 5 years, children of 5 –10 years, adolescents, pregnancy and postpartum
	Folic acid › *Population:* Children 6 months to 5 years, women of childbearing age, pregnancy and postpartum
	Micronutrient powders › *Population:* Children 6 months to 5 years (replacing iron and folic acid)
	Vitamin A › *Population:* Children 6 months to 5 years

[a] Fortified complementary food

[b] Fortified blended food

[c] Beverage made of corn flour and soy flour fortified with vitamins and minerals

[d] Fortified complementary food

[e] Nutritional supplement

Fortified foods in the commercial market

Information not available

Social protection programs that deliver rice

None

Legislative framework for rice fortification

Micronutrients to be used in rice fortification per the Central American Regulation Model – El Salvador, Guatemala, Nicaragua, Honduras and Costa Rica

Nutrients	Minimum levels of micronutrients in rice *	Minimum levels of micronutrients in the chemical compound of the nutrient to be used in rice fortification *
Iron	14.0 mg/kg	Iron bisglycinate
Selenium	256.0 µg/kg	Sodium selenite
Vitamin B_1	6.0 mg/kg	Thiamine mononitrate (5.3 mg/kg)
Vitamin B_3	51.0 mg/kg	Niacinamide
Vitamin B_6	5.6 mg/kg	Pyridoxine
Vitamin B_9	1.8 µg/kg	Folic acid
Vitamin B_{12}	10.0 µg/kg	Vitamin B_{12} 0.1% WS
Vitamin E	16.1 IU/kg	Tocopheryl acetate
Zinc	14.65 mg/kg	Zinc bisglycinate

* Adapted from the Codex Standard for Rice (Codex Stan 198–1995)

Rice consumption patterns

% who consume it daily: **–**

Consumption per person per day (in g): **30**

Annual per capita consumption (in kg): **11**

Characteristics of the rice industry

Rice production (in tons): **–**

Cultivation yield (t/ha): **2.07**

Number of mills: **25**

Area planted with rice (ha): **11,181**

Imports (tons): **71,089**

Source

Evelyn Roldán, Landscape Analysis for Rice Fortification: Guatemala. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

Haiti

Nutrition situation

Chronic malnutrition in children under 5 years	22%
Anemia	**By age group (%)**
6–11 months	–
6–59 months	65
Women of reproductive age	49
Pregnant women	–
Vitamin A deficiency (school age children)	32%
Zinc deficiency (children under 5)	30%

Source: Ayoya et al (2012) Precis of Nutrition of Children and Women in Haiti: Analyses of Data from 1995 to 2012; CNSA, Oxfam 2016. Rapport d'évaluation approfondie de la sécurité alimentaire dans le contexte de la sécheresse basée sur l'Approche de l'Economie de Ménages (AEM)

Government/public sector programs for fortification of food and complementary foods

Information not available

Fortified foods in the commercial market

Information not available

Social protection programs that deliver rice

None

Legislative framework for rice fortification

None

Rice Consumption patterns

% who consume it daily:

86% of homes consume it

76% of the population living on less than US$ 2/day consume 70% of rice

Consumption per person per day (in g): **–**

Annual per capita consumption (in kg): **–**

Characteristics of the rice industry

Cultivation yield (tons): **114,400**

Cultivation yield (t/ha): **2.07**

Number of mills: **500**

Area planted with rice (ha): **85,000**

Imports (tons): **415,000**

Source

Yves-Laurent Régis, Landscape Analysis for Rice Fortification: Haiti. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

Honduras

Nutrition situation

Chronic malnutrition in children under 5 years	23%
Anemia	**By age group (%)**
6–11 months	46%
6–59 months	25.7%
Women of reproductive age	18%
Pregnant women	22%
Vitamin A deficiency *	–
Zinc deficiency **	–

* Adequacy of > 150%. Only in rural and western regions a deficit occurs in 10% of households

** It is estimated that 85% of households have acceptable zinc consumption

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Sugar > *Fortificants:* Vitamin A
	Salt > *Fortificants:* Iodine
	Wheat flour > *Fortificants:* Iron, B-complex vitamins
Supplementation programs	Micronutrient powder (international cooperation)
	> *Fortificants:* Vitamins A, C, folic acid, zinc, iron
	Micronutrient powder (Mesoamerican initiative)
	> *Fortificants:* Vitamins A, D, E, C, B_1, B_2, B_3, B_6, B_{12}, folic acid, iron, zinc, copper, selenium, iodine

Fortified foods in the commercial market

Corn flour (voluntary fortification)

Social protection programs that deliver rice

School Feeding Program (WFP purchases)

Legislative framework for rice fortification

Micronutrients to be used in rice fortification per the Central American Regulation Model – El Salvador, Guatemala, Nicaragua, Honduras and Costa Rica

Nutrients	Minimum levels of micronutrients in rice *	Minimum levels of micronutrients in the chemical compound of the nutrient to be used in rice fortification *
Iron	14.0 mg/kg	Iron bisglycinate
Selenium	256.0 µg/kg	Sodium selenite
Vitamin B_1	6.0 mg/kg	Thiamine mononitrate
Vitamin B_3	51.0 mg/kg	Niacinamide
Vitamin B_6	5.6 mg/kg	Pyridoxine
Vitamin B_9	1.8 µg/kg	Folic acid
Vitamin B_{12}	10.0 µg/kg	Vitamin B_{12} 0.1% WS
Vitamin E	16.1 IU/kg	Tocopheryl acetate
Zinc	14.65 mg/kg	Zinc bisglycinate

* Adapted from the Codex Standard for Rice (Codex Stan 198–1995)

Rice consumption patterns

% who consume it daily: **97**

Consumption per person per day (in g): **99.4**

Annual per capita consumption (in kg): **36.4**

Characteristics of the rice industry

Rice production (in tons): **–**

Cultivation yield (t/ha): **2.3**

Number of mills: **21**

Area planted with rice (ha): **14,605**

Imports (tons): **159,917**

Source

Wilmer Bonilla, Landscape Analysis for Rice Fortification: Honduras. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

Panama

Nutrition situation

Chronic malnutrition in children under 5 years	19.1
Anemia	**By age group (%)**
6 –11 months	–
6 –59 months	36.0
Women of reproductive age	40.3
Pregnant women	36.4
Vitamin A deficiency (preschool children)	1.8%
Zinc deficiency (1–4 years)	–

Source: Survey of Living Standards 2008 / Global Nutrition Report 2015; Ministry of Health. National Survey of Vitamin A and Anemia. Panama, 1999

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Salt › *Fortificant:* Iodine
	Wheat flour › *Fortificants:* Vitamins B_1, B_2, B_3, folic acid, iron
Fortification of specific foods	Nourishing Corn Cream[a] › *Fortificants:* Vitamins A, E, B_1, B_3, B_6, B_{12}, folic acid, calcium, iron, zinc
	Fortified milk drink and biscuit (School Snack Program) › *Fortificants:* Vitamins, A, C, D, E, B_1, B_2, B_3, B_6, B_{12}, folic acid, calcium, phosphorus, magnesium, iron, zinc
	Fortified cream and biscuit (School Snack Program) › *Fortificants:* Vitamins, A, C, D, E, B_1, B_2, B_3, B_6, B_{12}, folic acid, calcium, phosphorus, magnesium, iron, zinc
Supplementation programs	Folic acid and iron › *Population:* Children with low birth weight (2–24 months) children at term (4–24 months), children 24–59 months, children of school age (5–12 years), women of childbearing age, pregnant and postpartum women
	Vitamin A › *Population:* Children 6–59 and postpartum women in priority districts

[a] Fortified complementary food

Fortified foods in the commercial market

Information not provided.

Social protection programs that deliver rice

SENAPAN food purchase bonus program

Legislative framework for rice fortification

Law 33 (June 26, 2009). Rice Fortification Program in the Republic of Panama. Not enforced.

Micronutrients recommended for rice fortification

Micronutrients	Natural content in white rice	Quantity to add (mg/kg)	Minimum	Average	Maximum
Vitamin B_1	0.7	5	3.1	5.7	8.3
Niacin	15	40	30.9	56.0	81.1
Vitamin B_6	1.9	4	3.0	5.4	7.8
Folic acid	0.1	1	0.6	1.1	1.6
Vitamin B_{12}	0	0.010	0.006	0.010	0.014
Iron (ferric pyrophosphate)	4.1	24	21.8	32.0	42.2
Zinc (oxide)	11.5	25	24.9	36.6	48.3

Source: Ministry of Health

Rice consumption patterns

% who consume it daily: **90**

Consumption per person per day (in g): **99.4**

Annual per capita consumption (in kg): **36.4**

Characteristics of the rice industry

Rice production (in tons): **139,616**

Cultivation yield (t/ha): **5.9**

Number of mills: **24**

Area planted with rice (ha): **86,120**

Imports (tons): **319,155**

Source

Victoria Valdés, Landscape Analysis for Rice Fortification: Panamá. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

Peru

Nutrition situation

Chronic malnutrition in children under 5 years	32,6%
Anemia	**By age group (%)**
6–11 months	–
6–59 months	32.6
Women of reproductive age	20.7
Pregnant women	28.0
Vitamin A deficiency (< 5 years of age)	11.7%
Zinc deficiency (1–4 years)	–

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Salt › *Fortificants*: Iodine, fluoride
	Wheat flour › *Fortificants:* Iron, folic acid, B_1, B_2, B_3
Supplementation programs	Micronutrient powders
	› *Fortificants:* Iron, zinc, Vitamin C, vitamin A and folic acid
	› *Population:* Children under 36 months
	Iron › *Population:* Children under 36 months
	Iron and folic acid › *Population:* Pregnant women
	Vitamin A › *Population:* Children and women at risk

Fortified foods in the commercial market

› Milk, Cereals

Social protection programs that currently deliver rice

› Glass of Milk National Program (rations program)
› Cuna Más National Program (day care program)
› Qali Warma (national school feeding program)

Legislative framework for rice fortification

None

Rice consumption patterns

% who consume it daily: **83.2**
Consumption per person per day (in g): **173**
Annual per capita consumption (in kg): **47.4**

Characteristics of the rice industry

Rice production (in tons): **3,128,794**
Cultivation yield (tons/ha): **7.7**
Number of mills: **627**
Area planted with rice: **–**
Imports (tons): **121,948**

Source

Laura Astete Robilliard, Landscape Analysis for Rice Fortification: Peru. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean. Link to full profile: **rebrand.ly/Country-Profiles**

Dominican Republic

Nutrition situation

Chronic malnutrition in children under 5 years	7.1%
Anemia	**By age group (%)**
6–11 months	–
6–59 months	28
Women of reproductive age	18%
Vitamin A deficiency (households) *	–
Zinc deficiency (households) **	–

* It is believed that among the poorest there is a moderate risk of 50%

** It is believed that among the poorest there is a moderate risk of 50%

Source: National Micronutrient Survey, 2012; Menchu et al, The Quality of the Diet of the Dominican Republic Approximate with the Data of the ENIGH-2007

Government | public sector programs for fortification of food and complementary foods

Mandatory fortification programs	Wheat flour › *Fortificants:* Iron, B_1, B_2, B_3, and folic acid at the minimum levels
Supplementation programs	Iron, folic acid, vitamin C › *Population:* Pregnant women, children 6–23 months old
	Vitamin A › *Population:* Women who have given birth, children aged 6 months to 4 years
	Calcium › *Population:* Pregnant and postpartum women

Fortified foods in the commercial market

› Premium rice

Social protection programs that deliver rice

Not available

Legislative framework for rice fortification

None

Rice Consumption patterns

% who consume it daily: **94.3**

Consumption per person per day (in g): **156.6**

Annual per capita consumption: **–**

Characteristics of the rice industry

Rice production (in tons): **11,812,172**

Cultivation yield (tons/ha): **–**

Number of mills: **300**

Area planted with rice (ha): **161,706**

Imports (tons): **377,385**

Source

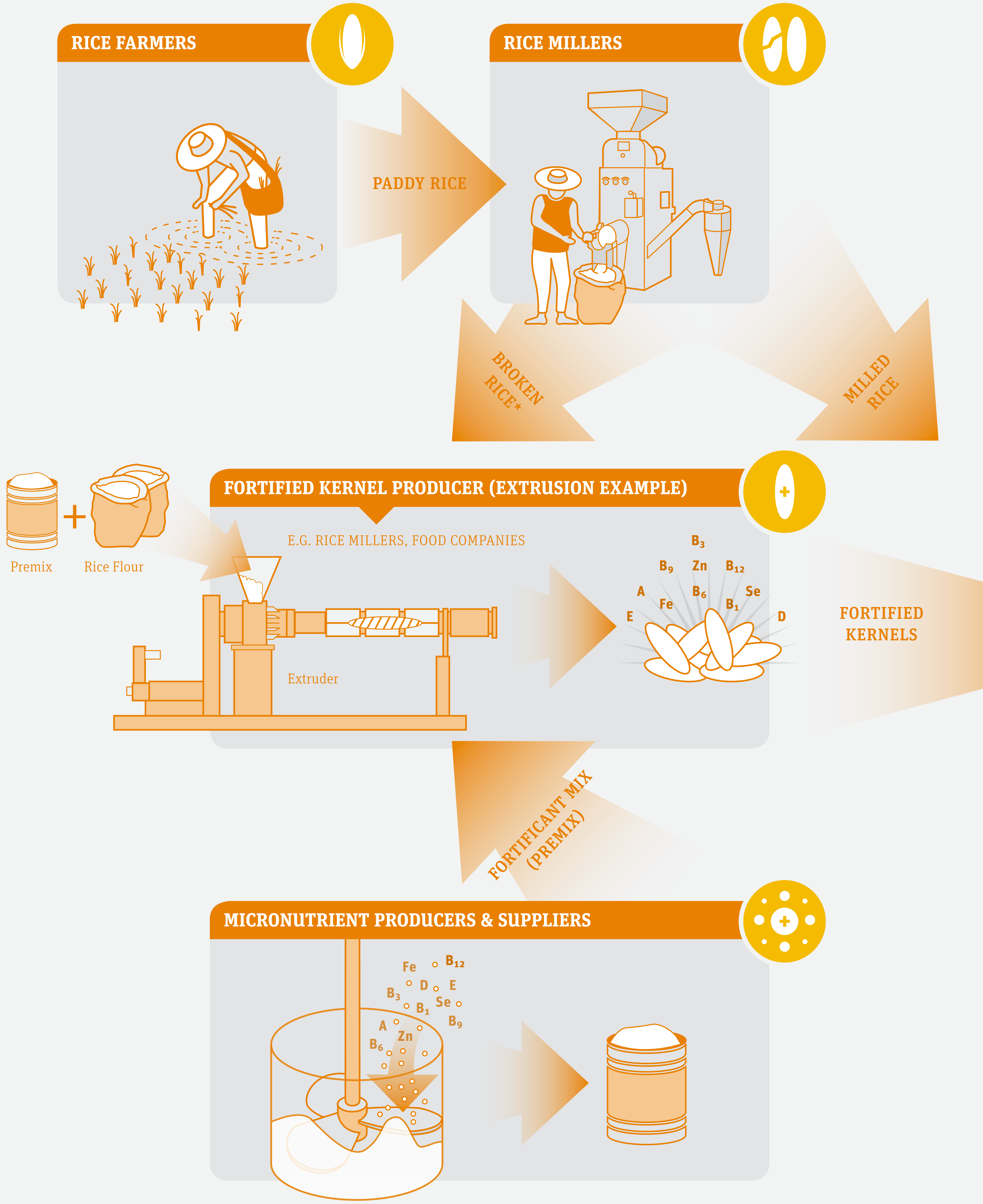
Andrea Cabral C., Landscape Analysis for Rice Fortification: Dominican Republic. Report presented to the World Food Programme Regional Bureau for Latin America and the Caribbean.

Link to full profile: **rebrand.ly/Country-Profiles**

Reference

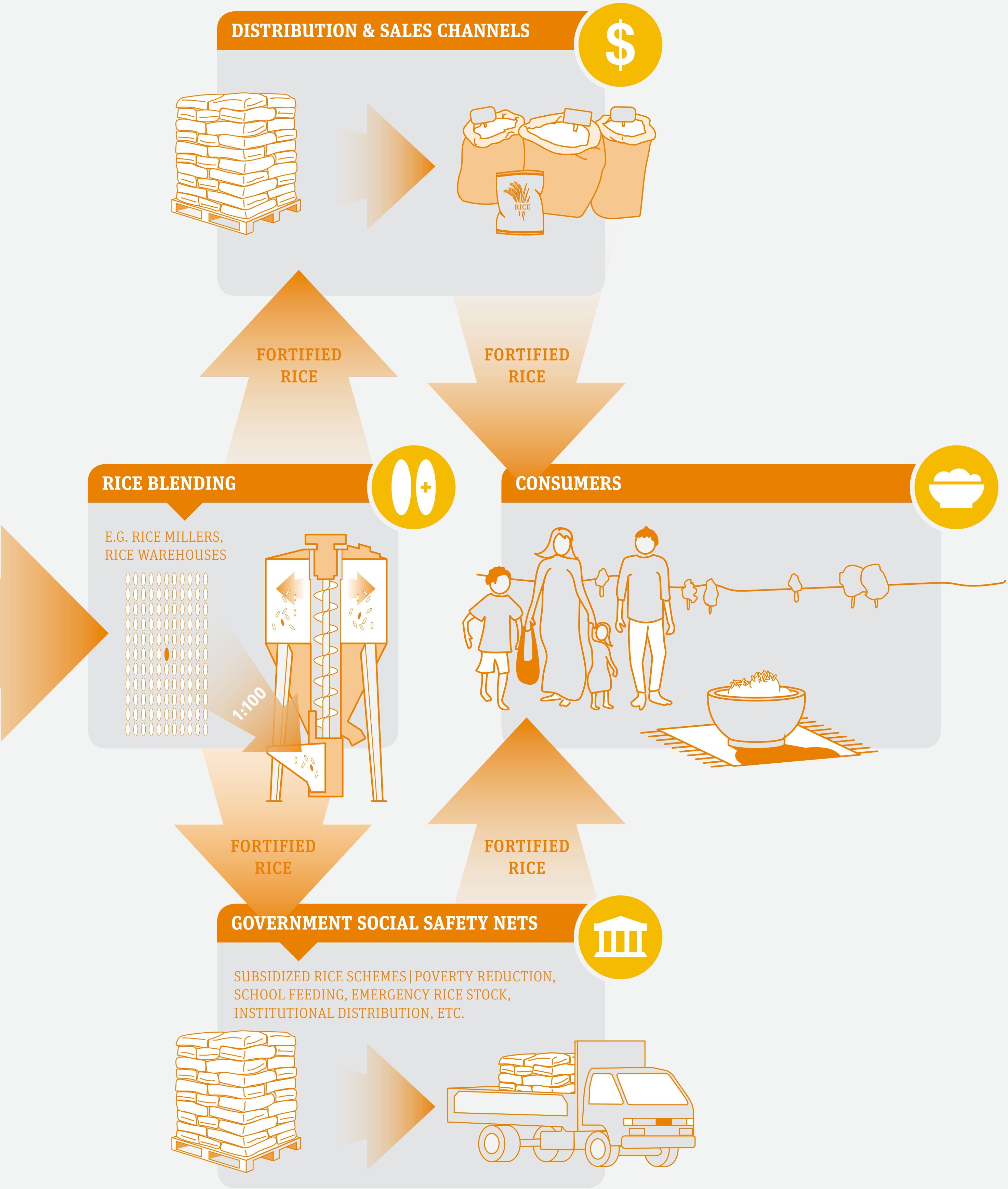
1. Yusufali, R., Ghoos, K. Landscape Analysis for Rice Fortification. Scaling Up Rice Fortification in Asia, *Sight and Life* on behalf of the World Food Programme, 2015.

FORTIFIED RICE SUPPLY



* For extrusion technology broken rice can be used to produce fortified kernels; with coating technology, head rice is required.

CHAIN



TERMINOLOGY **Paddy rice:** Rice kernels still enclosed in an inedible, protective hull (rough rice) **Head rice:** Unbroken grains of milled rice with the hull, bran, and germ removed **Milled rice:** polished rice is the regular-milled white rice. Hull, bran layer and germ have been removed. **Blending:** Mixing milled, non-fortified rice with fortified kernels in ratios between 0.5–2% to produce fortified rice. **Fortificant mix:** blend that contains several selected micronutrients (also referred to as premix) **Fortified kernels:** fortified rice-shaped kernels containing the fortificant mix (extrusion) or whole rice kernels coated with a fortificant mix (coating).

Scaling Up Rice Fortification in Latin America and the Caribbean

Workshop, Santo Domingo, Dominican Republic, 2016

The Scaling Up Rice Fortification in Latin America and the Caribbean event, held in Santo Domingo, Dominican Republic (August 2016), brought together over 100 stakeholders including government decision-makers and technical staff, and national, regional and international technical experts from various institutions and agencies including the United Nations (UN), academia, and the private sector. Country delegations attended from Colombia, Cuba, Dominican Republic, Guatemala, Haiti, Honduras, Panama and Peru. Two representatives from El Salvador attended as observers. The workshop was organized with the support of a Technical Advisory Group including members from the Food Fortification Initiative (FFI), the Institute of Nutrition of Central America and Panama (INCAP), the United States Agency for International Development (USAID), the Pan American Health Organization (PAHO), the World Food Programme (WFP), the Peruvian National Nutrition Institute (INN), and the Ministry of Health of Costa Rica.

The objectives of the event were to:

- Share global and regional evidence and existing operational experience
- Support countries in the process of developing a country-specific plan for rice fortification
- Facilitate the process of consultation and exchange of experience between countries in the region
- Create a network for continued learning and knowledge-sharing to support national efforts for rice fortification after the workshop.

The two-day workshop consisted of plenary presentations, guided country group work exercises, and moderated question and answer discussion sessions. In preparation for the workshop, a Landscape Analysis for Rice Fortification was conducted for each country as a means of assessing the potential influencing factors in the feasibility, sustainability and impact of rice fortification in each of the eight participating countries. During the workshop, the participants were presented with the regional justification for considering rice fortification, the global evidence for rice fortification, and technical aspects related to food fortification in the context of the double burden, conceptual frameworks and public policy instruments and the different technologies for rice fortification. In addition, three different national implementation models were presented: Costa Rica (mandatory), India and Bangladesh (both social safety net programs), and Brazil (voluntary program).

The workshop presenters and facilitators collaboratively reviewed all the presentations during a preparatory meeting.

FIGURE 1: Map of countries represented at the workshop

Miguel Barreto (Regional Director, World Food Programme, Regional Bureau for Latin America and the Caribbean) speaking at the opening of the at the Rice Fortification Workshop in the Dominican Republic 2016

Highlights of the workshop

The Vice President of the Dominican Republic, the Honorable Margarita Cedeño, who spoke fervently on the need for diversified interventions, inaugurated the event together with Lauren Landis, Global Director of WFP's Nutrition Division, and Miguel Barreto, WFP Regional Director for Latin America and the Caribbean.

> "We are betting on food security and on fortified rice"
>
> Margarita Cedeño,
> Vice-President, Dominican Republic

The opening presentation, "Micronutrient Situation in Latin America and the Caribbean" by Daniel López de Romaña of the Nutrition Research Institute of Peru, emphasized the health and economic risks posed by micronutrient deficiencies and illustrated the substantial gains of implementing adequate nutritional interventions to address them. A paper devoted to this work can be found on page 122 of this supplement.

The presentation "Global strategies for the prevention of micronutrient deficiencies with emphasis on rice fortification" by Gerardo Zamora, Technical Officer of the Evidence and Programme Guidance Division at the World Health Organization (WHO) in Geneva, described the guideline development process at WHO currently underway for rice fortification. The WHO recommendations for the prevention of micronutrient deficiencies through food fortification strategies were also presented. It is expected that the rice fortification guidelines put forth by WHO will establish a reference framework for governments and organizations to implement and tailor at the local level.

The presentation "Food fortification in the context of the double burden of malnutrition" by Omar Dary, Senior Nutrition Adviser at the United States Agency for International Development (USAID) confirmed that rice fortification is not at odds with existing efforts to combat the growing prevalence of overweight and obesity in the region. It was emphasized that the prevention of all forms of malnutrition depends on dietary diversity and the promotion of healthy lifestyles. In the context of Latin America, rice possesses all the necessary characteristics to be considered a suitable vehicle for micronutrient fortification.

The presentation "A bio-economic optimization model for improving the coherence and efficiency of micronutrient intervention programs in developing countries" by Stephen Vosti, Adjunct Professor of Agricultural and Resource Economics at the University of California, Davis, presented a methodology to estimate the benefits and costs of micronutrient intervention programs, and an economic optimization model for selecting efficient potential combinations of these programs, reflected in an article on page 176 of this issue.

As described in the presentation "Food fortification: summary of the evidence, current situation and challenges" by Helena Pachón, Research Associate Professor at Emory University and FFI, and Becky L Tsang, Technical Officer, FFI Asia, food fortification with micronutrients has the potential to impact public health, especially with iron. More information on this subject can be found on page 150 of this supplement.

Ana Victoria Román and Monica Guamuch from the Institute of Nutrition of Central America and Panama delivered the presentation "Conceptual frameworks and public policy instruments for the support of food fortification in Latin America: lessons learned and future challenges." Dr Román's contribution built upon Dr Pachón's by explaining the types of technical regulations and norms applicable to each delivery strategy. Different legal frameworks already in existence for food fortification were presented, as well as related public policies that could be built upon or referenced to support rice fortification as countries implement their programs. In turn, Dr Guamuch addressed the lessons learned in going from policies and legislation to the implementation of the program. It was established that legislation does not suffice and that political commitment to the strategy is a vital component for its development, implementation, and sustainability and to strengthen the programs as they are implemented. Emphasis was also placed on the importance of how rice production is organized in the country; program implementation is always easier when production is centralized. As a closing point, it was noted that control and inspection of fortified rice production is a key factor to sustain motivation and compromise from producers and to ensure that the nutrition goals set are met.

The first day of the workshop concluded with a presentation on Technologies for Rice Fortification. Hector Cori, Nutrition Science Director for DSM, presented the different rice fortification methods, including parboiling, dusting, coating and extrusion, and the benefits, limitations and costs associated with each method. Mr Jose Solera, Director of Operations at NTQ, presented the experience of a private company in Costa Rica that distributes most of the fortified rice in the country and uses coating technology. The lessons learned as part of the process, namely the importance of public-private collaboration and of training industrial partners on how to work with the product, the need for continuous monitoring of product quality conducted by a qualified laboratory and the importance of using a fortified kernel that is indistinguishable by the consumer, were also shared.

National rice fortification program models

Three national rice fortification program models were presented on Day 2 of the workshop. The case of Costa Rica was discussed to illustrate a mandatory program, followed by a presentation on India and Bangladesh, where fortified rice is distributed through social protection programs. A presentation about the experience of Brazil in promoting voluntary rice fortification was delivered as a third potential model for countries to contemplate based on their nutritional objectives.

Mandatory rice fortification

Melanie Ascencio (Ministry of Health, Costa Rica) and Jose Antonio Martínez (ANINSA) presented the mandatory rice fortification model of Costa Rica. Costa Rica has a long trajectory in the implementation of mandatory fortification programs. Given the high consumption of rice across all population groups, the Ministry of Health (MoH) of Costa Rica identified it as a suitable vehicle for micronutrient fortification to achieve a positive public health impact. For this reason the MoH who approached ANINSA, the National Association of Rice Producers, and CONARROZ, the National Rice Corporation of Costa Rica, to collaborate on the effort (more information can be found on page 217 of this supplement).

Distribution of fortified rice through social protection programs

Rizwan Yusufali of the WFP Regional Bureau in Asia presented the examples of Bangladesh and India, where fortified rice is delivered through social protection programs.

In Bangladesh, the National Strategy for the Prevention of Micronutrient Deficiencies includes food fortification. As was

Panelists at the Rice Fortification Workshop in the Dominican Republic, 2016

Regional and global experts and speakers at the Rice Fortification Workshop in the Dominican Republic, 2016

the case in Costa Rica, the initiative involved multi-stakeholder engagement, consisting of research, government, private sector and corporate partnerships. A research study was conducted early on to generate country-specific evidence on acceptance by the targeted population; encourage the distribution of the subsidized fortified rice targeting improved health; document nutrition and productivity benefits; and facilitate expansion and scaling-up.

Among the key success factors of this program, implemented exclusively through Government Social Safety Nets, the following stand out: **1)** a multisector approach to implementation, **2)** working in partnership with development partners, **3)** receiving technical support from experienced UN agencies and private corporations, and **4)** addressing the commercial sustainability issues for fortified rice to guarantee local production of the fortified kernel. Moving forward, challenges persist, including cost, marketing and the implementation of quality assurance protocols.

The government of India also decided to deliver fortified rice through its social safety net scheme, using targeted public distribution through midday school meals and integrated child development services. A number of studies have been carried out in the country to assess the acceptability and efficacy of the intervention to support advocacy efforts in different departments and ministries at the national and state level. In the context of India, a number of factors supported the continuance of the effort, specifically **1)** creating domestic capacity for fortified kernel production, **2)** a local evidence base, **3)** a systematic approach to implementation, **4)** the creation of a multidisciplinary technical advisory group, and **5)** high visibility of the intervention through the dissemination of results. Prevailing issues to be resolved include increasing domestic production capacity, lowering incremental cost, and ensuring the long-term suitability of the intervention.

Both examples are valuable to the Latin America and the Caribbean region, where social protection programs abound and are well established.

Voluntary rice fortification

Caroline Manus from the Global Alliance for Improved Nutrition (GAIN) presented the experience in Brazil with voluntary rice fortification. PATH and GAIN joined forces to develop a scale-up model through commercial channels; Brazil was chosen as a pilot country for this private-sector-driven initiative because of a variety of factors, namely:

- Industry consolidation
- Mature retail sector
- The experience of PATH in the country and
- A significant prevalence of micronutrient malnutrition among the urban and rural populations.

The project had the overall goal of developing new markets and driving commercial models at scale for a variety of fortified rice products to be produced and distributed in the country. Five main steps were carried out for this project: **1)** PATH worked with a private company to produce the fortified kernels, **2)** kernel technology was transferred to a local university, **3)** the project approached three large supermarket chains, and **4)** a social marketing campaign was developed based on extensive market research. The project was successful in reaching over 2.5 million consumers, engaging the three largest national retailers, establishing the foundational architecture for rice fortification and generating knowledge on the commercial implementation of this strategy. Through this project it was also concluded that a purely commercial, private-sector-driven initiative is not sufficient to reach a meaningful scale in a reasonably short time line (3–5 years) and that governance structure is a major determinant of reach.

Country group work

The afternoon of Day 2 was devoted in its entirety to country group work. Each country delegation worked with two facilitators on discussing the plans for their potential rice fortification program. Two exercises were carried out, the first was dedicated to identifying the challenges and national capacities and the second to the elaboration of a work plan. The exercises proved to be useful, allowing participants to think about and discuss, guided by an expert, diverse factors associated with launching a strategy, including a situation analysis (general awareness of micronutrient deficiencies, political will, human and financial resources, potential intervention model, acceptance, delivery mechanisms, among others). It should be noted that country landscape analyses (described in depth elsewhere in this supplement, see page 199), were commissioned in preparation for the workshop and used as an aid during the discussions.

Primary conclusions and lessons learned

Rice is a staple food in several countries of Latin America and the Caribbean. Cuba, Dominican Republic, Haiti, Panama, and Peru have very high consumption patterns *per capita*, while Colombia, Honduras and Guatemala have lower consumption per capita, but one that is substantial among the most vulnerable populations. Given that official guidelines for rice fortification are being prepared by WHO and sufficient scientific and practical evidence at country level is available to confirm the safety and efficacy of this approach, rice fortification is a viable complementary strategy to improve micronutrient health in the region.

"Rice fortification is a viable complementary strategy to improve micronutrient health in the region"

In the region, important opportunities were identified for the distribution of fortified rice through social protection programs, and some, such as the Dominican Republic, expressed interest in large-scale, mandatory, implementation. In order to achieve the reach and impact desired, it is important that all key actors understand the value and potential impact of the intervention, as well as its limitations, for eliminating micronutrient deficiencies. Particularly now, when the prevalence of overweight and obesity is one of the most pressing public health concerns, it should be noted that rice fortification is not at odds with existing overweight and obesity prevention efforts.

From a practical standpoint, neither governments nor millers should be left alone or expected to promote the strategy independently. All existing examples worldwide confirm that rice fortification efforts are most successful when partnerships are formed that include the public and private sector as well as other parties that can provide support in key areas such as advocacy, management, implementation and monitoring, among others. The question of financial resources is also a frequent barrier and concern to both the public and the private sector. Hence addressing it early on, and identifying novel ways to remedy high initial costs to one party, is absolutely necessary, as the long-term gains are dramatically more significant.

It is the hope of the organizing committee of this workshop that we built upon the existing interest in rice fortification in the region, and that the plans started at the workshop will mature into well designed, sustainable programs that can contribute to the improvement of the micronutrient status in the region.

Rice Fortification in Costa Rica

Case study

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Ministry of Health Costa Rica

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Key Messages

- Costa Rica's long history of food fortification provided the knowledge base and legislative experience for implementing a successful mandatory rice fortification program.
- Engaging food manufacturers and rice millers, and leveraging existing distribution channels, created a sustainable fortification program.
- The public and private sector share costs to develop and support ongoing quality management and monitoring.
- The technology and fortificants used produce fortified rice kernels that are acceptable in taste and appearance to consumers.

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Seal of quality as fortified food in Costa Rica

Introduction

With a population of approximately four million people, Costa Rica has a long history of government policies to improve the country's public health. Public health initiatives include large-scale food fortification, strengthening the primary health care system, sanitation improvements, and deworming campaigns.

All rice consumed in Costa Rica is fortified with folic acid, vitamins B_1 (thiamin), B_3 (niacin), B_{12} (cobalamin), E, selenium and zinc. As a staple food, 60% of the rice is domestically produced. The fortification of rice, along with that of other staple foods and condiments, helps to increase micronutrient intake. Per capita rice consumption averages 150 g per day, providing approximately 30% of caloric intake. Rice is relatively affordable, and is about 9% of the cost of the basic food basket.

Costa Rica's success in large-scale rice fortification is primarily due to its food fortification experience, its centralized rice industry, government leadership, and private sector support. This article describes Costa Rica's fortified rice program and analyzes the key factors in its success.

> "Costa Rica's success in large-scale rice fortification is primarily due to its food fortification experience, its centralized rice industry, government leadership, and private sector support"

Staple food fortification in Costa Rica

Micronutrient fortification of staple foods and condiments in Costa Rica began in 1974 with the iodization of salt in response to continued micronutrient deficiencies. Despite the implementation of a basic sanitation and deworming program, primary health care strategy, supplementation, health promotion, and complementary feeding activities to improve micronutrient health, the 1996 national nutrition survey found that micronutrient deficiencies

TABLE 1: Overview of fortified foods, fortificants and fortification levels in Costa Rica

Food	Average daily consumption	Fortificants	Fortification level
Rice	130 g	Folic acid (vitamin B_9)	1.8 mg/kg
		Thiamin (vitamin B_1)	6.0 mg/kg
		Cobalamin (vitamin B_{12})	10.0 µg /kg
		Niacin (vitamin B_3)	50.0 mg/kg
		Vitamin E	15.0 IU/kg
		Selenium	105.0 µg/kg
		Zinc	19.0 mg/kg
Sugar	71.4 g	Vitamin A	8 mg/kg (26,664 IU/kg)
Wheat flour	74 g	Thiamin (vitamin B_1)	6.2 mg/kg
		Riboflavin (vitamin B_2)	47.2 mg/kg
		Niacin (vitamin B_3)	55 mg/kg
		Folic acid (vitamin B_9)	1.8 mg/kg
		Iron (Ferrous fumarate)	55 mg/kg
Milk	107 mL	Iron (Ferrous bisglycinate)	1.4 mg/250 mL
		Vitamin A	180 µg/250 mL
		Folic acid (vitamin B_9)	40 µg/250 mL
Maize flour	18.0 g	Iron (Ferrous bisglycinate)	22 mg/kg
		Niacin (vitamin B_3)	45 mg/kg
		Thiamin (vitamin B_1)	4 mg/kg
		Riboflavin (vitamin B_2)	2.5 mg/kg
		Folic acid (vitamin B_9)	1.3 mg/kg
Salt	9.8 g	Iodine	30–60 mg/kg
		Fluoride	175–225 mg/kg

remained at critical levels.[1] In addition, a study based on data from the nation's Congenital Disease Registry showed that 12 in 10,000 infants had neural tube defects.[2]

In response, the government established a cross-sectoral National Micronutrient Commission and expanded its fortification efforts, in partnership with the private sector. Mandatory fortification of wheat flour began in 1997, followed by corn flour in 1999, milk and rice in 2001, and sugar in 2003. See **Table 1** for an overview of the fortified foods in Costa Rica and the fortification level.

Legislative framework for rice fortification

In 2001, the Presidency of the Republic and the Ministry of Health enacted the "Regulations for the Enrichment of Rice." The legal framework for rice fortification was placed under the umbrella of the 1974 General Health Law. The legislation mandated that all direct for human consumption rice must be fortified, whether the rice is domestically produced or imported. The regulations defined the specific micronutrients and the required fortificant levels. In addition, the regulations assigned external monitoring and quality control to the government and internal monitoring to the rice industry.

Fortified rice supply chain

Costa Rica's rice supply chain is relatively consolidated. Two fortified kernel producers supply the 11 rice milling companies operating in Costa Rica. The millers blend the fortified kernels with non-fortified rice at the specified ratio (0.5%) and sell the fortified rice through their distribution channels. The 11 millers are brought together under the National Association of Rice Producers (ANINSA). The rice corporation (CONARROZ) is the sole entity allowed to import rice within a set quota.

Setting standards

Setting rice fortification standards started with consideration of the typical local diet, including consumption of other fortified foods. Other criteria used in selecting the micronutrients and levels of the rice fortificant premix included: the nutrient deficiencies in the population; the interaction between nutrients; the recommended nutritional intake; and the level of rice consumption. The combined micronutrient intake from fortified rice and other fortified foods was determined to be effective and safe. Based on these considerations, the standard was set to require fortification with vitamin B_1 (thiamin), B_3 (niacin), B_9 (folic acid), vitamin B_{12} (cobalamin), vitamin E, selenium, and zinc.

In Costa Rica rice is not fortified with iron and vitamin B_2 (riboflavin) for two reasons. First, tests showed that the type and concentration of iron recommended at the time (2001) produced changes in both taste and appearance that were unacceptable to consumers. Unless color change is not a problem for consumer acceptability, rice is typically not fortified with vitamin B_2 because it changes the color of fortified kernels. Second, iron and vitamin B_2 were available in other fortified commodities. Note that new formulations of iron are now available that do not impact consumer acceptability of fortified rice.

Technology

In Costa Rica, where rice is washed prior to cooking, the initial preference to fortify using dusting technology was deemed inappropriate. Dusting technology, in which polished, milled rice kernels are dusted with a fortificant mix, does not allow for washing or cooking in excess water, as this will wash out the micronutrients. Rather, coating and extrusion technologies were determined to be more suitable for the production of the fortified kernels, as nutrients are retained when rice is washed or cooked in excess water.

Currently, one of the fortified kernel producers uses coating technology and the other producer uses warm-extrusion technology. Refer to the contribution by Montgomery et al for additional information on identification of appropriate rice fortification technology (p. 159).

Quality control

Quality control and monitoring responsibilities are shared by the private and public sectors. The two fortified kernel producers are responsible for guaranteeing the micronutrient concentrations in the fortified kernels.[3] Millers are responsible for the accuracy of the blending ratios and homogeneity. For internal monitoring of the blending ratios, sampling is conducted every hour. Some sampling, along with all lab analysis, is done by third-party laboratories to determine compliance against the mandatory rice fortification executive decree. External quality control and evaluation are the responsibility of the Ministry of Health, and are performed by the government's quality control agency. These quality control samples are obtained from retailers at point of sale, as opposed to upstream sampling at manufacturing sites. Government regulations mandate labeling of all rice sold with the assigned quantities of the micronutrients' minimum amounts (per kg). The shared quality control and monitoring process enhances quality control across the supply chain.

Costs

Costs for rice fortification include initial start-up costs and ongoing costs of fortification. Initial costs included the cost of the coating and extrusion technology and the blending machinery, as well as installation and calibration. Ongoing, the primary cost components are: the micronutrient premix costs; production costs of the fortified kernels; and quality control and monitoring costs. Minor costs include blending, storage and transport. In the early days of the program, costs due to fortification rose to about 5–6% of the retail price. As fortified kernel producers and rice millers gained experience and increased production efficiencies, the additional costs fell to less than 1%. This cost-reducing gain in production efficiency is typically observed in food fortification programs. Currently, the estimated additional cost per kg of rice due to fortification is about US$ 0.01, or about 0.9% of the retail price.

Impact of micronutrient fortification programs

Although improvements cannot be attributed to any specific fortified food, national impact evaluation and monitoring programs have reported significant improvements in micronutrient status following the introduction of the food fortification program. Given the relatively large per capita intake of fortified rice as part of the overall food basket, rice fortification must have significantly contributed to these improvements in micronutrient status. Reductions in micronutrient deficiencies have been shown both within the general population and among specific groups.

> "Significant improvements in micronutrient status have been reported following the introduction of the food fortification program"

Anemia

Costa Rica's anemia prevalence rates have fallen significantly following the introduction of the national fortification program.[4] In addition to iron deficiency, anemia can also result from deficiencies in vitamin B_{12} and folate. The 2008–2009 National Survey data,[5] compared to the 1996 data,[1] showed a 71.2% reduction in the prevalence of anemia among children one to six years of age. Rural areas showed larger reductions in the prevalence of anemia (89.6%) than urban areas (74.6%). National anemia prevalence ranges from 1 to 9.9% and is no longer of public health concern (see **Figures 1** and **2**).

Among women of childbearing age, the National Nutrition Surveys in 1982, 1996[1] and 2008–09[5] showed a similar significant reduction in anemia prevalence of 46.8% at the national level. Looking at geographic areas, anemia declined 54% in rural areas, 46.3% in urban areas, and 36.4% in metropolitan areas (see **Figures 3** and **4**).

FIGURE 1: Prevalence of anemia in Costa Rican preschool children; 1982 and 1996 compared to 2008–2009.

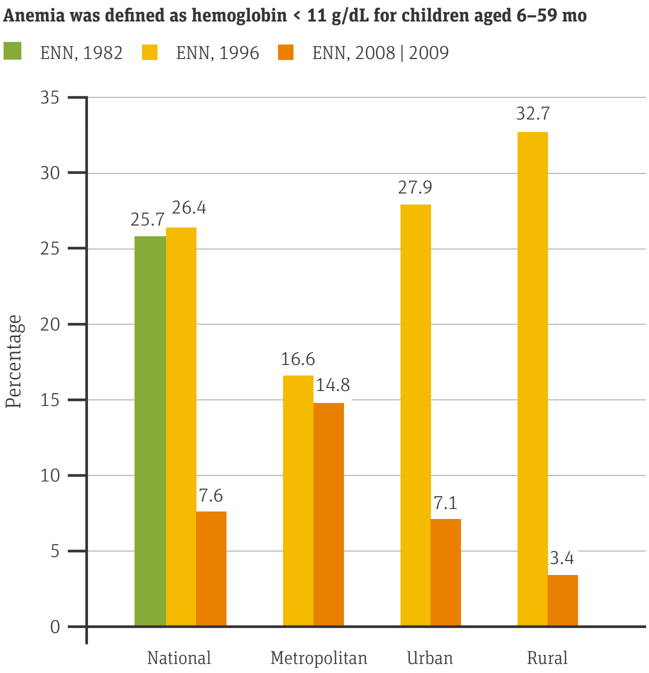
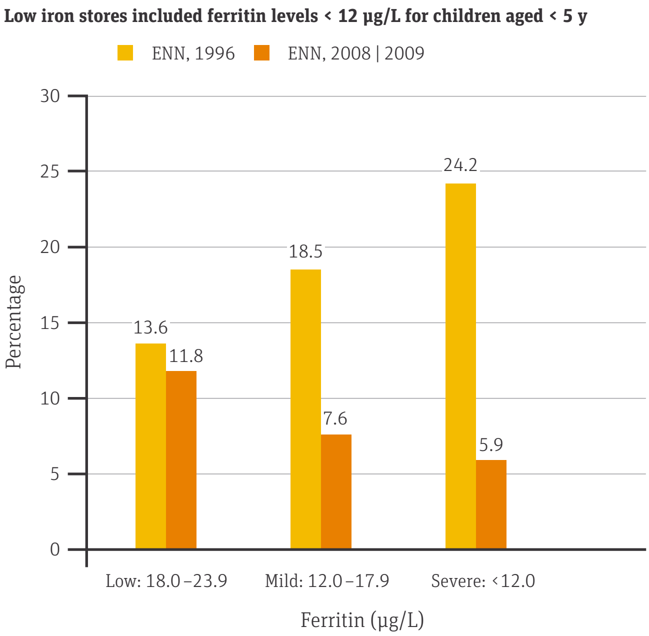


FIGURE 2: Prevalence of low ferritin in Costa Rican preschool children; 1996 compared to 2008–2009.



Neural tube defects

The combined food fortification programs have also reduced the prevalence of neural tube defects (NTDs) linked to folate deficiency. Prevalence of NTDs in newborns fell from 11 per 10,000 births in 1982–1996[1] to five per 10,000 births in 2008–2009[5] (see **Figure 5**).

Key success factors

The success of rice fortification in Costa Rica is due to the following factors:

- Government leadership

Government leadership has been crucial to the establishment and implementation of the rice fortification program. The early success of other large-scale food fortification efforts and the existence of the government's cross-sector commission created an enabling environment for the passage of mandatory rice fortification legislation. The government worked in collaboration with the private sector to ensure sustainability. In addition, the government maintained the political will for legislative monitoring and enforcement, including incentives to reinforce compliance and punishments for non-compliance.

"Government leadership was crucial in establishing and implementing the rice fortification program"

- Sustainable partnership approach: engaging rice millers and leveraging existing distribution channels

The Costa Rican government worked in partnership with the private sector from the start of the program. Negotiations with the rice producers' association were supported, and the private sector was given sufficient time to implement the mandatory fortification. Importantly, as the price of rice is controlled, the Ministry of Economy included the cost of fortification within the cost model in determining the wholesale and retail prices.

Millers and distributors leveraged the pre-existing channels to produce and distribute the fortified rice. Two private sector food companies manufacture the fortified kernels. The government helped to study the different premix options and costs, taking into account the market price. Based on the government analysis of the most efficient supply chain structure, fortified kernel producers invested in developing blending technology to be installed at the rice millers.

Costs and responsibilities were shared between public and private sectors

A significant portion of the cost to develop a rice fortification

FIGURE 3: Prevalence of anemia in Costa Rican women of childbearing age by area; 1982 and 1996 compared to 2008–2009.

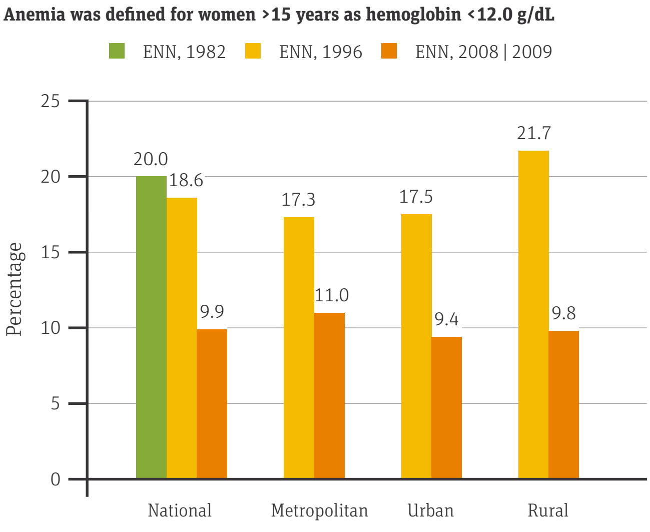
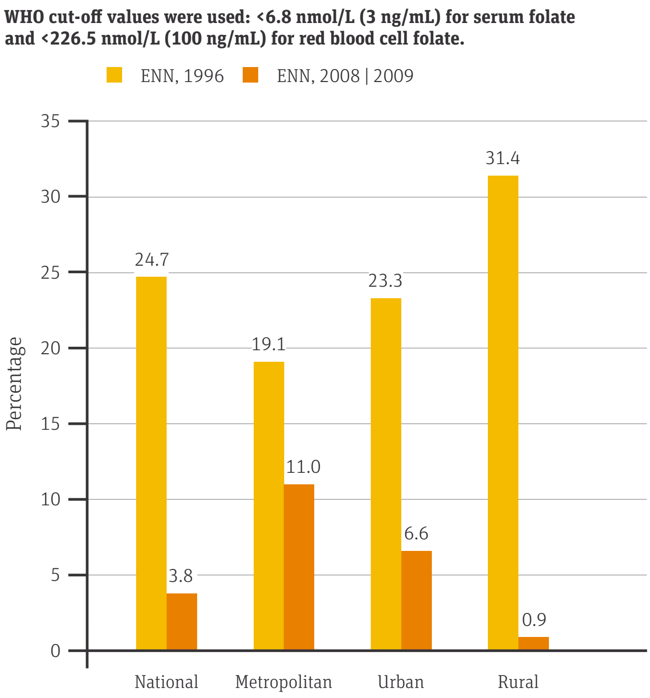


FIGURE 4: Prevalence of folate deficiency in Costa Rican women of childbearing age by area; 1996 compared to 2008–2009.



program was covered by the private sector, thus increasing the program's sustainability. The Ministry of Health financed the health needs research, while technology development was financed by the fortified kernel producers seeking profit opportunities. Two companies, Kuruba and DSM, led technology development and premix tests for the fortified kernels. The Institute of Nutrition of Central America and Panama (INCAP) led technology assessment and micronutrient stability tests. In addition, one of the fortified kernel suppliers supported the industry by investing in the development of blending technology. Advocacy for implementation of the mandate was led by the rice producers' association, ANINSA, and the national rice corporation, CONARROZ. These private and civic sector efforts helped ensure sustainability. The government's only costs to maintain the program are the laboratory equipment and labor necessary for on-going monitoring, evaluation, and quality-control activities.

Consumer prices were controlled

The Ministry of Economy Trade and Industry controls rice prices at the wholesale and retail levels, by accounting for the added cost of fortification. Demand for rice is relatively inelastic. As mentioned previously, initially retail rice prices rose by 5–6%. However, after more experience in production helped reduce costs, retail prices fell. The current retail price increase due to fortification is only 0.9%.

It is important to note that mandatory fortification eliminated the need to create consumer demand, which has proven difficult for fortified staples. Rice distributors are able to cover the minimal increase in their costs through the government-mandated price without the need to spend additional resources on marketing and consumer demand generation.

Good consumer acceptability

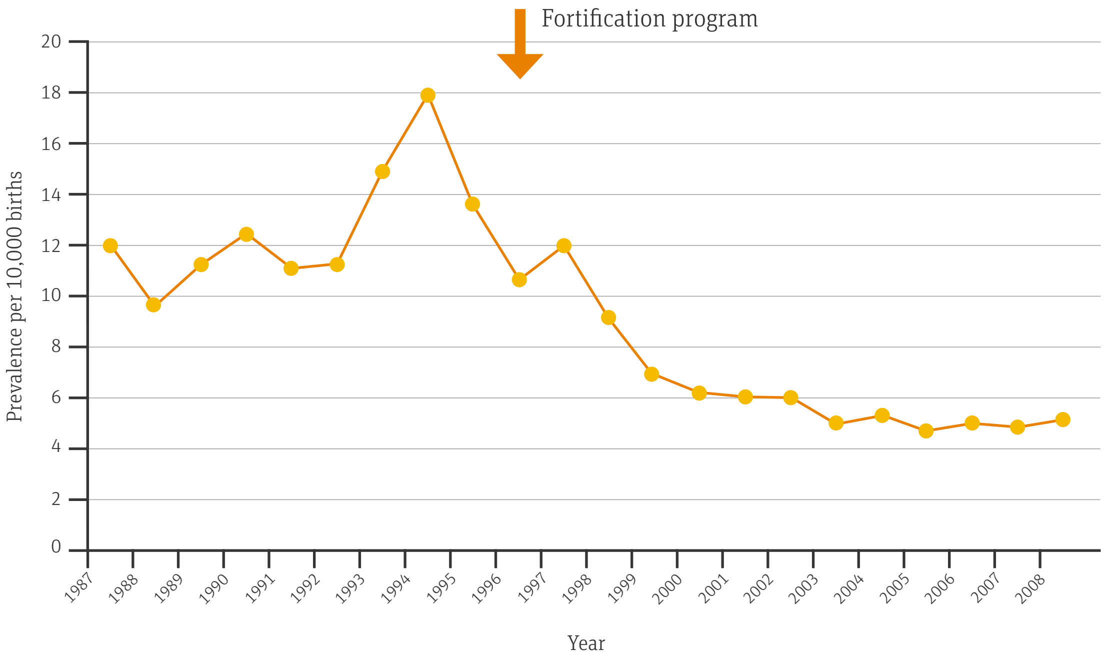
As consumers cannot tell the difference between Costa Rica's fortified and non-fortified rice, consumer acceptability is high. Tests showed that rice produced according to government standards can be washed without losing nutrients, and looks, smells and tastes the same as non-fortified rice.

> "Costa Rica's rice fortification program exemplifies successful implementation"

Conclusion

Costa Rica is a model for successful implementation of a rice fortification program. Program success is attributed to the country's experience with fortification of other commodities; the centralized rice industry; a good understanding of the rice

FIGURE 5: Birth prevalence of neural tube defects (NTDs) in Costa Rica; 1987–2008



Blending of fortified kernels with non-fortified rice at rice mill in Costa Rica

industry landscape and supply chain; strong government leadership; early involvement and support from both private and public sectors; and a strong emphasis on the importance of monitoring and compliance. The government also monitored the positive public health impact of the fortification program. Costa Rica's experience demonstrates that, when feasible, mandatory fortification is a very cost-effective delivery option. Mandatory fortification eliminates the need for price-increasing marketing efforts and consumer awareness campaigns.

Overall, the Costa Rican experience provides valuable lessons for implementing a successful rice fortification program. Although the rice milling landscape in many countries is more fragmented, making implementation more complex, from a technology, organizational and public health perspective, Costa Rica demonstrates that rice fortification can be implemented successfully, and can significantly contribute to the reduction of micronutrient deficiencies.

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Glossary

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Anemia
Characterized by reduction in hemoglobin concentrations or the size and color of red blood cells, which impairs the ability to supply oxygen to the body's tissues. Anemia is caused by inadequate intake and/or poor absorption or excessive losses of iron, folate, vitamin B_{12} and other nutrients. It can also be caused by infectious diseases (inflammation) such as malaria, hookworm infestation and schistosomiasis, and by genetic variants of hemoglobin. Women and children are high-risk populations. Clinical signs include fatigue, pallor (paleness), breathlessness and headaches.

Bioavailability
Bioavailability refers to the proportion of a nutrient that is absorbed from the diet and utilized for normal body functions. The ease by which the body absorbs specific micronutrients is determined by its molecular form and the interaction between different specific micronutrients and other substances in the diet.

Biofortification
Practice of improving the nutrient content of plants before harvesting through breeding (e.g. new rice variety with higher iron content) and/ or genetic engineering (e.g. Golden Rice). The key difference between biofortified rice and fortified rice is that rice fortification implies adding nutrients to rice post-harvesting, while biofortification aims to make more nutritious rice varieties available through breeding or GMO. While current biofortified rice cultivars contain higher levels of one micronutrient, fortified rice can contain a range of several micronutrients.

Blending
Mixing of milled, non-fortified rice with fortified kernels in ratios between 0.5% and 2% to produce fortified rice. Blending can be done at a rice miller, warehouse, or other location where rice is centrally processed. Small-scale blending technology is also available.

Brown rice
Rice with only the hull removed. Bran layers and rice germ remain, giving the rice a brownish color. Brown rice is still a rich source of vitamins B_1, B_6, E and niacin, most of which are removed during polishing/milling.

Coating
Technology to make fortified kernels. Rice kernels are coated with a fortificant mix plus ingredients such as waxes and gums. The micronutrients are sprayed onto the rice grain's surface. The coated rice kernels are blended with non-fortified rice in a ratio between 0.5% and 2%.

Dusting
Technology to make fortified rice. Polished milled rice kernels are dusted with a fortificant mix in powder form. This technology is only used in the United States and does not allow for washing, pre-cooking or cooking in excess water, since this will wash out the micronutrients.

Effectiveness
Refers to the impact of an intervention in practice (real-life conditions). Compared to efficacy, the effectiveness of a fortification program will be limited by factors such as non-consumption or low consumption of the fortified food.

Efficacy
Refers to the capacity of an intervention such as fortification to achieve the desired impact under ideal circumstances. This usually refers to experimental, well-supervised and controlled intervention trials.

Essential micronutrient
Refers to any micronutrient (vitamin or mineral), which is needed for normal growth, development and function by the body in miniscule amounts throughout the life cycle. Micronutrients are normally consumed as part of a healthy and diverse diet. They either cannot be synthesized in adequate amounts by the body at all, or else cannot be synthesized in amounts adequate for good health. They thus must be obtained from a dietary source.

Estimated average requirements (EAR)
EAR is the average (median) daily nutrient intake level estimated to meet the needs of half the healthy individuals in a particular age and gender group.

Evaluation
Systematic assessment using criteria governed by a set of standards to help in decision-making. The primary purpose of evaluation, in addition to gaining insight into prior or existing interventions, is to enable reflection and assist in the identification of future change. For fortification programs, this means assessing the effectiveness and impact of the program on the targeted population, and to provide evidence that the program is achieving its nutritional goals.

Extrusion
Technology to make fortified kernels. Rice-shaped reconstituted kernels are produced by passing rice flour dough, containing a fortificant mix, through an extruder. The extruded kernels, which are made to resemble rice grains, are then blended into non-fortified rice in a ratio between 0.5% and 2%, similar to the coating technology. Extrusion allows for the use of broken rice kernels as an input, and may be carried out under hot, warm, or cold temperatures, which influences the appearance and performance of the final fortified kernel.

Fortificant
Selected essential micronutrient in a particular form to fortify selected food (e.g., rice, flour, salt).

Fortificant mix
Blend that contains several fortificants, also referred to as premix.

Fortification
Practice of deliberately increasing the content of essential micronutrient(s), i.e., vitamins and minerals, in a food, so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health. The essential micronutrients are added to make the food more nutritious post-harvesting.

Fortification of rice distributed through social safety nets
Targeted rice fortification can be achieved by fortifying rice distributed through social safety nets, such as school feeding programs, distributions to the poor or vulnerable groups, food for work programs, and food aid during emergency situations. As social safety nets in most cases target the most vulnerable population groups, fortifying rice distributed through social safety nets will reach the most vulnerable populations and has great potential to make a significant impact on public health.

Fortified kernels
Fortified rice-shaped kernels containing the fortificant mix (extrusion) or whole rice kernels coated with a fortificant mix (coating). Fortified kernels are blended with non-fortified rice in a ratio between 0.5% and 2% to produce fortified rice.

Fortified rice
Rice fortified with fortificant mix by dusting, or non-fortified rice combined with the fortified kernels in a 0.5%–2% ratio. Typically fortified kernels are blended with non-fortified rice in 1:100 (1%) ratio.

Mandatory fortification
Mandated and regulated fortification of specific food commodities by the government sector through legislation. This means that all foods to which the legislation refers should be fortified according to the prescribed specifications.

Micronutrient deficiencies
A form of malnutrition caused by an insufficient intake of vitamins and minerals (also known as micronutrients), which are essential for human health, growth, development and function; also referred to as micronutrient malnutrition or hidden hunger. Micronutrient deficiencies are one of the main causes of poor health and disability, and affect over two billion people worldwide.

Micronutrient deficiency diseases
When certain micronutrients are severely deficient owing to insufficient dietary intake, insufficient absorption and/or suboptimal utilization of vitamins or minerals, specific clinical signs and symptoms may develop, e.g., night blindness and xerophthalmia for vitamin A deficiency or rickets for vitamin D deficiency.

Milled rice
Polished rice is the regular milled white rice. Hull, bran layer and germ have been removed, and so have most of the vitamins. See also brown rice and parboiled rice.

Monitoring
Observing and checking progress or quality of a program over a period of time. For fortification programs it refers to the continuous collection and review of information on program implementation activities for the purposes of identifying problems (such as non-compliance) and taking corrective actions so that the program fulfils its stated objectives.

Non-fortified rice
Milled rice without fortification.

Nutrient requirement
Refers to the lowest continuing intake level of a nutrient that will maintain a defined level of nutrition in an individual for a given criterion of nutritional adequacy.

Parboiled rice
Rice that has been partially boiled in the husk. The three basic steps of parboiling are soaking, steaming and drying. Parboiling makes rice easier to process by hand, boosts its nutritional profile and changes its texture. Parboiling drives water-soluble nutrients from the bran to endosperm, hence parboiled white rice contains roughly half the water-soluble vitamins from brown rice, and is more nutritious than regular milled rice.

Quality assurance (QA)
Refers to the implementation of planned and systematic activities necessary to ensure that products or services meet quality standards. The performance of quality assurance can be expressed numerically as the results of quality control exercises.

Quality control (QC)
Refers to the techniques and assessments used to document compliance of the product with established technical standards, through the use of objective and measurable indicators.

Recommended nutrient intake (RNI)
RNI is the daily intake that meets the nutrient requirements of almost all apparently healthy individuals in an age- and sex-specific population group.

Regulatory monitoring
Comprises both internal and external monitoring; regulatory monitoring at the retail level is also referred to as commercial monitoring. The primary aim of regulatory monitoring is to ensure that the fortified foods meet the nutrient, quality and safety standards set prior to program implementation. Once regulatory monitoring has demonstrated that the program is operating in a satisfactory manner, evaluation of the program can be undertaken to assess its impact.

Tolerable upper intake level (UL)
Highest average daily nutrient intake level that is considered to pose no risk of adverse health effects to almost all (97.5%) apparently healthy individuals in an age- and sex-specific population group. The UL applies to daily use for a prolonged period of time for healthy individuals with no deficits to be corrected.

Voluntary fortification
A market-driven approach, with the fortified food product marketed as a “value-added” for the consumer. This approach relies on consumer awareness and education, demand, and willingness and ability to pay slightly more for the fortified product.

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