Introduction to Rice Fortification

Peiman Milani
Sight and Life

Scott Montgomery
Food Fortification Initiative

Carla Mejia
World Food Programme

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 status.
- 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 anywhere between 1 and 10%. As rice fortification is scaled up, it will achieve economies of scale, which will reduce costs.

Introduction

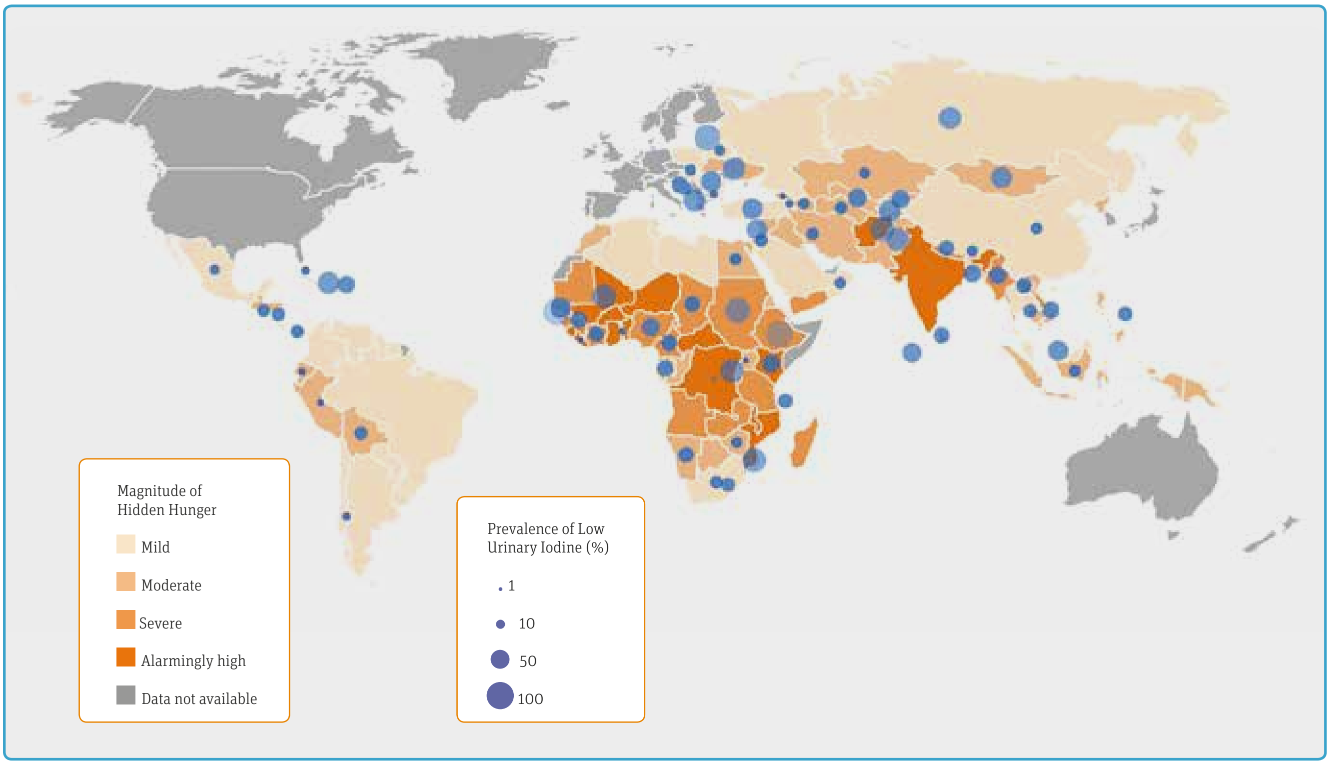
Micronutrient deficiencies affect more than two billion people worldwide and are especially prevalent in developing countries. Also referred to as hidden hunger, micronutrient deficiencies impair physical growth and cognitive development and have long-term effects on health, learning ability and productivity. 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 the 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

FIGURE 1: Hidden Hunger Map[8]



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. 111).

The 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, and 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 yet 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 10 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 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

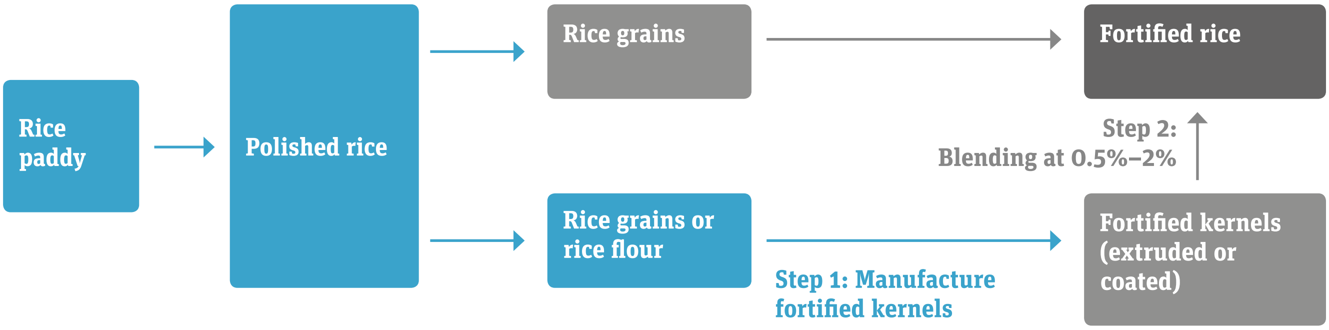


Chart adapted from Steiger 2012

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 fortification with iodine 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 thiamine, niacin and iron. This resulted in the successful elimination of beriberi, a severe public health problem caused by thiamine deficiency. In 1952, the Philippines pioneered the first mandatory rice fortification legislation requiring all rice millers and wholesalers to enrich the rice they milled or traded.[9]

Since these early efforts, the past decade has seen a significant evolution of cost-effective rice fortification technologies that are unlocking opportunities to 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 manufacturing of fortified kernels containing appropriate vitamins and minerals, and blending the fortified kernels with milled rice to create fortified rice. 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.

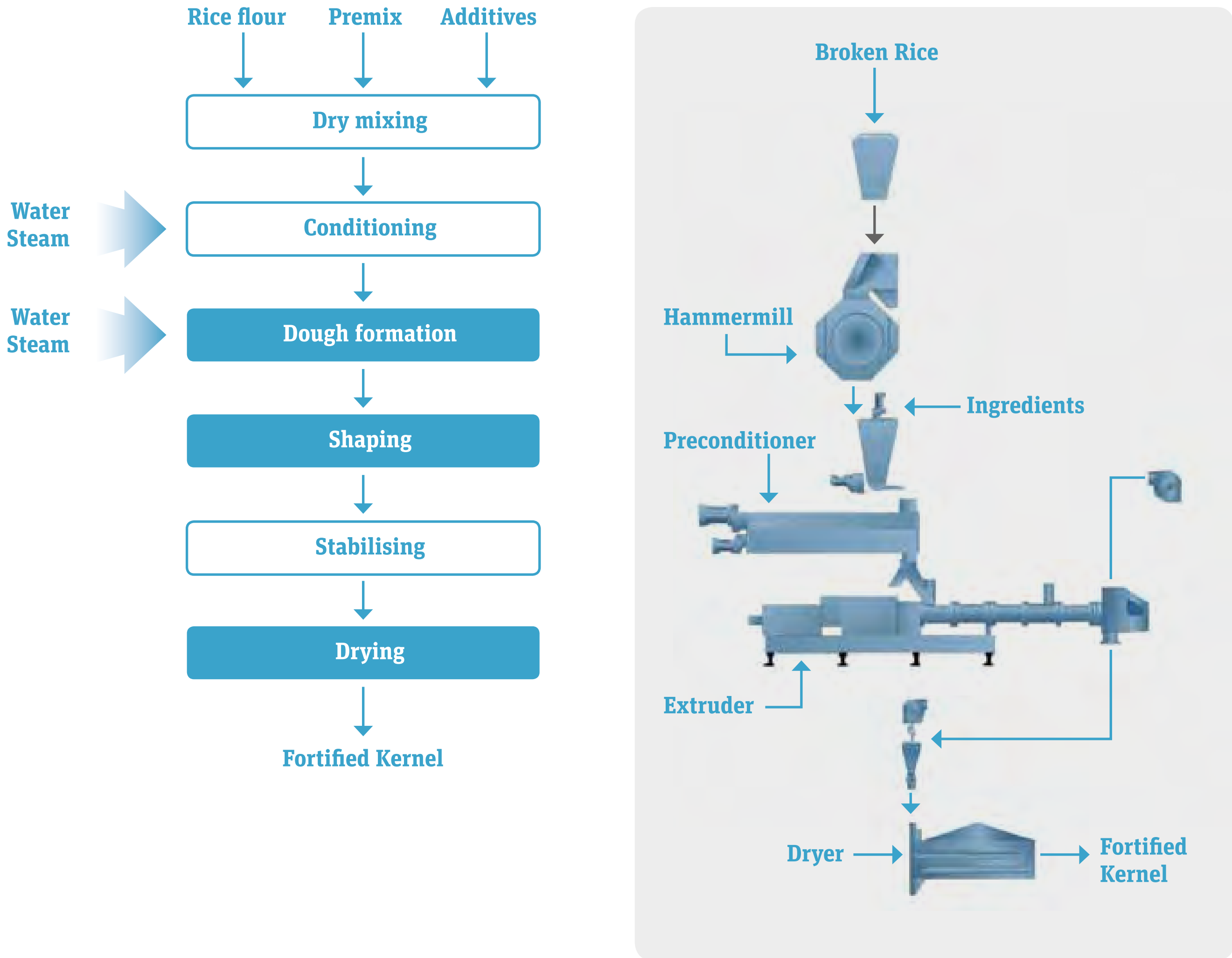
Extrusion and rinse-resistant coating technologies produce fortified rice that is effective and acceptable to consumers in color, taste and texture. Although a third fortification technology – dusting – is used in the United States and a few other countries, it provides limited nutrient protection when rice is washed, soaked or cooked in excess water that is then discarded. Dusting is appropriate in countries where rice is not washed prior to cooking, nor cooked in excess water.

Fortified kernel production technologies

Coating

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

FIGURE 3: Basic extrusion steps



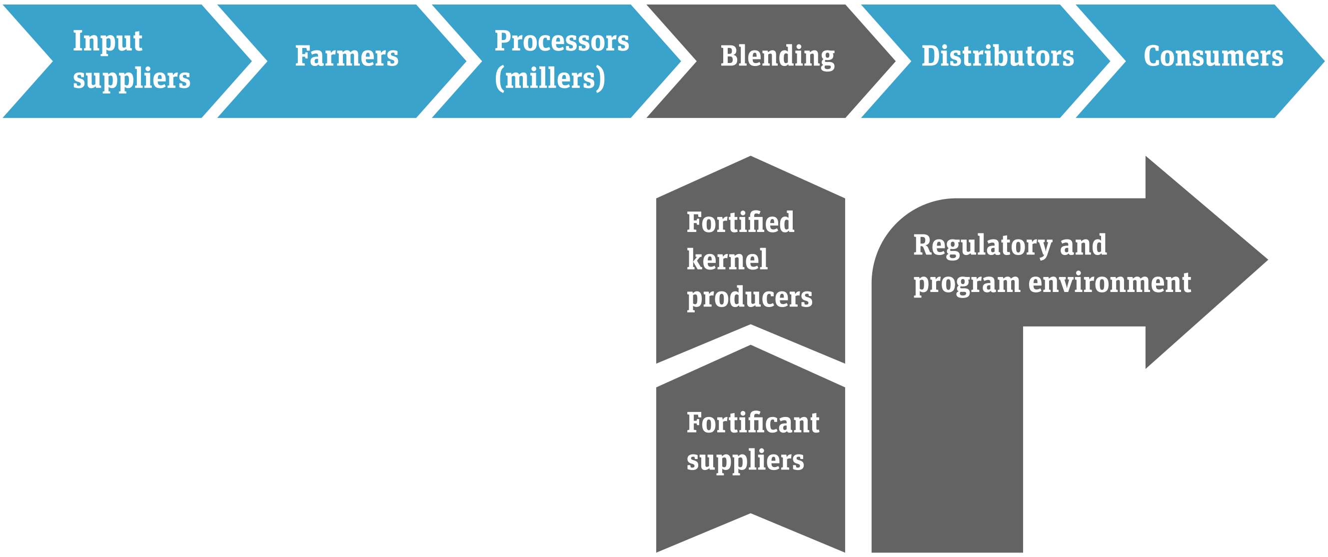
is evenly spray-coated with micronutrients and the additional ingredients. This is usually done in large rotational drum or pan-coating machines. The coated kernels are then dried to yield fortified kernels. This technology concentrates the micronutrients on the surface of the rice grains. When cooked, 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. This method of producing fortified kernels is not recommended when rice is cooked in excess water that is later discarded.

Extrusion

Extruded fortified kernels are formed by combining water and a fortificant mix with rice flour that is usually made from grinding lower value and non-contaminated broken rice to form a dough (**Figure 3**). 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.

Although initially extrusion was done at room temperature ('cold extrusion'), this approach has been all but abandoned in favor of the use of heat for improved sensory properties and kernel stability. Hot extrusion (60°C–110°C) uses equipment of various degrees of sophistication – from steam-enhanced pasta presses to large-scale double screw extruders – to 'shape' the dough into kernels that more closely resemble non-fortified rice. The process may include a preconditioner and an emulsifier (monoglyceride) added to maintain stability during storage of the fortified kernels. The resulting fortified kernels closely resemble different types of rice, with various degrees of translucency and texture.[2] Fortified kernels made via hot extrusion are similar to non-fortified rice in their uptake of water during cooking, cooking time and firmness.

FIGURE 3: Rice fortification supply chain



Blending process

As shown in **Figure 4**, when rice fortification is introduced, the rice supply chain is adapted to incorporate fortified kernel production and blending. The blending ratio, typically between 0.5% and 2%, depends on the nutrient content of the fortified kernels, the desired level of fortification, and organoleptic and consumer acceptance considerations. Quality assurance and quality control are needed to ensure uniform blending at the correct ratio.

Integrating rice fortification into the rice supply chain

Conducting a rice landscape analysis 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 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 available 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 advisable to consider fortification with the following micronutrients: iron, vitamin A, vitamin B_9 (folic acid), vitamin B_6 (pyridoxine), vitamin B_{12} (cobalamin), vitamin B_1 (thiamine), vitamin B_3 (niacin) and zinc.[10] Among these and upon reviewing the evidence, the World Health Organization (WHO) has singled out iron fortification as a strong recommendation and vitamin A and folic acid as conditional recommendations. Overall, the determination of which micronutrients to include and at what level depends on the target population's micronutrient intake, the prevalence of micronutrient deficiencies and the population's 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. Wherever appropriate and feasible, regional standards may benefit countries with similar fortification needs from a scale and trade perspective. For additional information on the evidence for recommended micronutrients and standards, please refer to the WHO Guideline on rice fortification[11] as well as the contributions of de Pee et al (Evidence, p. 55 and Standards, p. 63).

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

Extruded fortified rice

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. Other interventions such as iron/folate or multiple micronutrient supplementation will therefore still be required. Young children aged six 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 gaps. For additional information on specific micronutrient needs across the lifecycle, please refer to Figure 4 in the contribution by Rudert et al (p. 87).

> "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"

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, whereby 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.

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. 68).

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.[12]

Rice fortification costs fall into two main categories: program costs and supply chain costs. The former are typically incurred by the public and social sectors – governments, funders, program implementers and regulatory agencies – while the latter are usually borne by the private sector – fortified kernel producers, rice millers, food companies and retailers. 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, Africa 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, Africa and Latin America can seize the momentum and lead the way in building effective and sustainable rice fortification programs.

References & notes on the text

1. Allen L, de Benoist B, Dary O, et al, eds. Guidelines on food fortification with micronutrients. Geneva: WHO/FAO; 2006.
2. 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. 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. Beretta Piccoli N, Grede N, de Pee S, et al. Rice fortification: its potential for improving micronutrient intake and steps required for implementation at scale. Food Nutr Bull 2012;33(4):S360–S372.
4. Black RE, Allen LH, Bhutta ZA, et al. for the Maternal and Child Undernutrition Study Group. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008;371:243–260.
5. Bhutta ZA, Das JK, Rivzi, A et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet 2013;382:452–77.
6. Copenhagen Consensus Center. Copenhagen Consensus III. 2012. Internet: www.copenhagenconsensus.com/copenhagen-consensus-3 (accessed 18 May 2015).
7. Haddad L. Ending undernutrition: our legacy to the post 2015 generation. Sussex, UK: Institute of Development Studies in partnership with the Children's Investment Fund Foundation; 2013.
8. Muthayya S, Rah JH, Sugimoto JD, et al. The global hidden hunger indices and maps: an advocacy tool for action. PLOS ONE 2013;8(6):e67860. doi: 10.1371/journal.pone.0067860 (adapted from source).
9. Forsman C, Milani P, Schondebare JA, et al. Rice fortification: a comparative analysis in mandated settings. Ann N Y Acad Sci 2014;1324:67–81.
10. de Pee S. Proposing nutrients and nutrient levels for rice fortification. Ann N Y Acad Sci 2014;1324:55–66.
11. WHO. Guideline: fortification of rice with vitamins and minerals as a public health strategy. Geneva: WHO; 2018. Internet: http://apps.who.int/iris/handle/10665/272535 (accessed 22 May 2018).
12. Roks E. Review of the cost components of introducing industrially fortified rice. Ann N Y Acad Sci 2014;1324:82–91.