Rice Fortification's Impact on Nutrition

Food Fortification Initiative
Enhancing Grains for Healthier Lives

Vitamin and Mineral Deficiencies and Public Health

Thirty percent of the global population is affected by vitamin and mineral deficiencies that have negative health outcomes (1). Fortification of staple foods has been shown to effectively reduce the burden these conditions place on vulnerable populations.

Why and How to Fortify Rice?

Because rice loses a large percentage of several key nutrients during the milling process (2), individuals that rely heavily on rice for their energy needs often do not receive adequate nutrition. This suggests that in areas where it is a staple food, rice has the potential to be a good vehicle for fortification as even small increases in nutrient levels could have a positive health impact.

Rice is a staple food consumed by more than half of the world's population. In 59 countries, an average of at least 75 grams of rice is available per person per day (3). The total population of these countries is 4.1 billion. Reaching even half of that population would ensure a greater daily nutrient intake among 2 billion people. However, currently only 5 nations have legal mandates for rice fortification: Costa Rica, Nicaragua, Panama, Papua New Guinea, and the Philippines (4). Despite legislation in these countries, only Costa Rica and Papua New Guinea fortify the majority of their rice.

> **Opportunity**
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> ***Rice is a staple food consumed by more than half of the world's population, thus rice fortification provides an avenue to help combat micronutrient deficiencies.***

Rice can be fortified using dusting, coating, or extrusion technologies. Of these, the latter two involve the blending of fortified kernels with non-fortified rice, typically at a ratio of 1:100. Coating and extrusion technologies retain nutrient content after washing and cooking by commonly used methods, while mimicking the look of non-fortified rice (5). The cost of fortification is estimated to be 10-20 U.S. dollars per metric ton of rice (5). These costs are minimal compared to the health and economic costs that result from micronutrient deficiencies (5) and could further decline as more countries implement rice fortification programs (2). Thus, fortification is economically feasible and the technical capability exists to improve nutrition through rice fortification.

Efficacy of Rice Fortification

Twelve rice fortification efficacy studies from published literature were reviewed. These studies, carried out in controlled environments, compared a variety of health outcomes between individuals who received fortified rice and those who received non-fortified rice (6-17). They were conducted in Brazil, India, Mexico, the Philippines, and Thailand, and typically used rice kernels produced by extrusion technology. Rice was fortified with various nutrients including iron, folic acid, thiamin, niacin, vitamin A, and vitamin B12. The results from the outcomes assessed are summarized in the table below.

Overall, the strongest evidence for rice fortification was observed for iron-related outcomes. Statistically significant improvements were observed in 5 out of the 8 studies that assessed serum ferritin, 6 out of 7 of the studies that assessed iron deficiency, and in both studies that assessed iron body stores. Following these observations, the studies were separated into those that fortified rice with iron only, and studies that fortified rice with multiple micronutrients (including iron).

Nine of the studies investigated rice fortified with iron only (6-14). Five out of 6 studies observed increases in ferritin levels, and 5 out of 5 reported reductions in the prevalence of iron deficiency. Both iron-related indicators (ferritin, iron deficiency) improved in 5 out of the 5 studies that delivered at least 13 mg/d of iron.

Only 3 of the studies reviewed assessed the impact of rice fortified with multiple micronutrients (15-17). None of these 3 studies reported statistically significant improvements in serum ferritin levels; only one study found a reduction in the prevalence of iron deficiency. Reasons for lack of significant results in these studies may be because an insufficient amount of iron was added to the rice. All of the multiple micronutrient studies used fortification levels that delivered less than 13 mg/d of iron and observed little improvement in iron indicators. However, all of the iron-only studies that delivered at least 13 mg/d of iron reported statistically significant improvements in iron-related indicators. This observation is consistent with the recommendation that about 14 mg/d of electrolytic iron should be delivered through wheat flour fortification (18). Similar recommendations for rice fortification have not been made, however ferric pyrophosphate (which is commonly used in rice fortification) and electrolytic iron (which is commonly used in wheat flour fortification) have a similar bioavailability—which is about 50% of the bioavailability from ferrous sulfate meaning twice as much iron should be added for fortification. Considering the observed results, future multi-micronutrient studies should consider increasing the amount of iron added or using an alternate iron compound. Other factors, such as interactions between the multiple micronutrients may have influenced the results, but this is difficult to elucidate due to the small number of studies. The fact that the study populations were not consistent between all studies also makes comparing results difficult.

Two studies investigated rice fortified with vitamin A, but were not included in the table because there was no comparison group that was given non-fortified rice (19, 20). Both of these studies were conducted in night-blind pregnant women. One study compared an intervention group that received vitamin A fortified rice, plus iron and riboflavin delivered via capsule, to a comparison group that received vitamin A fortified rice only (19). Compared to the comparison group, a statistically significant improvement was observed in pupillary threshold, but not in plasma retinol. The other study compared 6 groups that were given vitamin A through various forms, one of which was through fortified rice (20). A statistically significant improvement in pupillary threshold and plasma were observed in all groups. Future studies that investigate other populations and include a non-fortified rice comparison group will be helpful in better understanding the efficacy of vitamin A rice fortification.

Effectiveness of Global Rice Fortification Programs

When rice fortification is implemented on a large scale, more of the population can receive the health benefits. Four published studies investigated the effectiveness of rice fortification after implementation on a wide scale in Costa Rica, the Philippines, and Thailand (21-24). The one study that assessed hemoglobin and anemia found statistically significant improvements in these outcomes among children (24). Other outcomes investigated by these studies included beriberi, morbidity, and neural tube defects (NTDs) (21, 23, 24). The study investigating NTDs was conducted in Costa Rica. Costa Rica added folic acid to wheat and maize flour and saw a subsequent decline in NTDs. A further decline was observed after rice and milk were fortified with folic acid (21). This suggests that rice and milk fortification may have contributed to the additional decreases in the birth prevalence of NTDs. Due to the small number of investigations, additional effectiveness studies are necessary to better understand the impact rice fortification may have at the population level.

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Table. Summary of outcomes assessed and study results among 12 published studies that investigated the efficacy of rice fortification[1].

Outcome assessed (unit)	*Number of studies that found significant improvement in this outcome*	*Total number of studies that investigated this outcome*
Hemoglobin (g/L)	4	11
Anemia (%)	5	8
Serum ferritin (µmol/L)	5	8
Iron deficiency (%)	6	7
Plasma retinol (µmol/l)	1	4
Transferrin receptor (mg/L)	2	4
Iron-deficiency anemia (%)	0	3
C-reactive protein (mg/L)	0	3
Iron body stores (mg/kg)	2	2
Zinc protoporphyrin (µmol/mol heme)	1	2
Serum zinc (µmol/L)	1	1
Blood lead (µg/dl)	1	1
Elevated C-reactive protein (%)	1	1
Homocysteine (µmol/L)	1	1
Plasma B12 (pmol/L)	1	1
Total body reserves of retinol (µmol)	1	1
Serum thiamin (nmol/L)	0	1
Vitamin A deficiency (%)	0	1
Zinc deficiency (%)	0	1

[1] *Studies were considered to have found significant improvements in an outcome if a statistically significant ($p<0.05$) change was seen in the outcome from baseline to study end in the intervention group that received fortified rice versus a comparison group that received non-fortified rice.*

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