#TheIndiaDialog Working Paper Series

Working Paper (WP–2023–007 August, 2023)[1]

Journey of Rice Fortification in India

Amit Kapoor[2] and Mukul Anand[3]

US Asia Technology Management Center
521, Memorial Way, Knight Building
Stanford University

Institute for Competitiveness
155, National Media Center
Gurgaon, Haryana, India

[1] The views presented here are those of the authors and do not necessarily represent the position of either Institute for Competitiveness or Stanford University. Working papers are in draft form. This working paper is distributed for purposes of comment and discussion only.

[2] Chair, Institute for Competitiveness and Lecturer, US – ATMC, Stanford University

[3] Researcher, Institute for Competitiveness

Journey of Rice Fortification in India

Etymologically, patient means sufferer. It is not suffering as such that is most deeply feared but suffering that degrades.

-Susan Sontag, Illness as Metaphor

In the spoonful a mother or father feeds to a toddler, food is love.

Henrietta H. Fore, The State of World's Children 2019

Introduction

Malnutrition extends beyond mere hunger and affects every country worldwide, presenting one of the greatest global health challenges. It encompasses diverse conditions, including undernutrition (wasting, stunting, underweight), deficiencies in essential vitamins and minerals, overweight, obesity, and diet-related noncommunicable diseases (NCDs). (Branca, 2017)

Malnutrition is a distressing condition that affects millions of people worldwide, with severe consequences on physical, mental, and emotional health. Physically, malnutrition can lead to stunting, wasting, and micronutrient deficiencies, hindering growth and development, impairing learning abilities, and impacting productivity. Mentally, malnutrition can cause depression, anxiety, and cognitive impairment, affecting social interactions and problem-solving abilities. Emotionally, it may lead to feelings of shame, isolation, and hopelessness, making it challenging for individuals to cope with daily challenges and thrive in their communities.

Despite efforts to combat malnutrition, it continues to be a major public health concern specifically in LMICs. Since the late 2000s, micronutrient-related malnutrition, a component of the broader "triple burden of malnutrition," has garnered significant attention. Micronutrient deficiencies alone have been estimated to cause an annual gross domestic product loss of 2% to 5% in LMICs, with direct costs amounting to around US$20 to US$30 billion per year (Osendarp, et al., 2018). As of 2021, approximately 2.3 billion people, accounting for nearly 29.3% of the global population, experienced moderate to severe food insecurity, marking an increase from 25.4% before the pandemic (2022 Global Nutrition Report: Stronger commitments for greater action, 2022).

Children and pregnant women in LMICs are at significant risk due to micronutrient deficiencies, with an estimated 155 million children under 5 years suffering from stunting in 2016. Tragically, around 45% of deaths among children under 5 are attributed to undernutrition. Furthermore, in 2020, 149 million children under 5 were stunted, 45 million were wasted, and 38.9 million were overweight or obese on a global scale. (Branca, 2017)

Iodine, vitamin A, and iron deficiencies pose substantial threats to health and development, especially among children and pregnant women in low-income countries. Unhealthy diets and poor nutrition are leading risk factors for cardiovascular diseases, specific cancers, and diabetes worldwide. (Branca, 2017)

BOX 1

The World Bank classifies economies (or countries) into four groups based on gross national income (GNI) per capita.

The classifications and thresholds for the current 2024 fiscal year, using data from 2022 are:

• Low-income economies: GNI per capita of $1,135 or less. (Afghanistan, Madagascar, Ethiopia, etc.)

• Lower middle-income economies **(LMICs):** GNI per capita between $1,136 and $4,465. (Myanmar, Zimbabwe, India, etc.)

• Upper middle-income economies: GNI per capita between $4,466 and $13,845. (Mexico, Malaysia, South Africa, etc.)

• High-income economies: GNI per capita of $13,846 or more. (UAE, UK, US, Taiwan, etc.)

The global nutrition crisis, which was already concerning before the Covid-19 outbreak, has worsened significantly. The number of people affected by hunger surged by 150 million since 2019, reaching 768 million in 2021. Moreover, those unable to afford a healthy diet increased by 112 million, totalling 3.1 billion in 2020 alone. (2022 Global Nutrition Report: Stronger commitments for greater action, 2022). Additionally, nutrition directly impacts SDGs 2 and 3 and indirectly influences SDGs 1, 4, 5, 6, and 8. (Romana, Grieg, Thompson, & Arabi, 2021)

1. SDG 2: "End hunger, achieve food security, and improve nutrition" is affected by malnutrition due to its impact on sustainable agriculture and food security.
2. SDG 3: "Ensure healthy lives and promote well-being for all at all ages" is affected due to the increased risk of infections and diseases caused by malnutrition.
3. SDG 1: "No Poverty" is indirectly affected as malnutrition decreases earning capacity, increasing the risk of poverty.
4. SDG 4: "Quality Education" is indirectly affected as malnutrition hinders development potential, impacting access to quality education.
5. SDG 5: "Gender Equality" is indirectly affected as empowering women to claim their rights improves nutrition and quality of life, leading to better education and job opportunities.
6. SDG 6: "Clean Water and Sanitation" is indirectly affected by malnutrition's broader impact on public health and well-being.
7. SDG 8: "Decent Work and Economic Growth" is indirectly impacted as proper nutrition improves learning performance, translating into better job opportunities.

The data presented above reveals a concerning picture of hunger and malnutrition. Moreover, the interconnection between malnutrition and SDG goals underscores the crucial role of nutrition in achieving those goals. Therefore, addressing malnutrition in all its forms is imperative, considering its significant impact on global health and well-being. Urgent action is required to tackle this pervasive issue.

Scope of the problem

A reduction in malnutrition levels in a population would require a multi-pronged approach rather than a single approach as global experiences have shown. Within the realm of malnutrition, micronutrient induced malnutrition is of specific concern. Micronutrients are vitamin and minerals which, are required in relatively much smaller amount than, for example, protein or carbohydrates. Still, they are the buildings blocks for good health and overall well-being.

Micronutrients are indispensable in helping foetuses, infants, and children grow and thrive. They help in avoiding serious birth defects, undeveloped cognitive ability, maternal and infant deaths, childhood blindness and reduction in productivity. Normally, humans cannot produce micronutrients inside their bodies except vitamin D (although the ability of human body to absorb vitamin D is dependent on several other micronutrients especially calcium and zinc). As a result, over the course history, humans have strived to consume as much varied diet as possible in order to ingest as many micronutrients as possible in good enough amounts. Yet, micronutrients are found lacking in large part of populations all over the globe including India.

TABLE 1: An estimate of the overall prevalence of micronutrient deficiencies in India

Micronutrient	Prevalence
Vitamin D deficiency	**61%**
Iron deficiency	**54%**
Vitamin B12 deficiency	**53%**
Folic acid deficiency	**37%**
Vitamin A deficiency	**19%**
Iodine deficiency	**17%**

Pooled prevalence from children (0–5 years), adolescents (<18 years), adults (>18 years) and pregnant women.

Source: (Venkatesh, et al., 2021)

Thus, micronutrients need to be a part of everyday diet because they can only be consumed from external sources. However, the global diet continues to fall short of the minimum standards for healthy and sustainable eating, leading to a rise in obesity and diet-related non-communicable diseases (NCDs). Currently, around 40% of all adults and 20% of all children are overweight or obese (2022 Global Nutrition Report: Stronger commitments for greater action, 2022).

Despite existing policy interventions[4], these trends remain unaltered, and factors such as ongoing conflicts worldwide, including recent events like the war in Ukraine, and the impacts of climate change, contribute to the escalating rates of malnutrition. This poses a significant threat to countries facing food and nutrition insecurity, especially vulnerable populations. (2022 Global Nutrition Report: Stronger commitments for greater action, 2022)

In India, as per SPI[5] 2022, on average, only 12.32% of children aged 6-23 months receive an adequate diet in Aspirational Districts[6] (ADP districts). Over 690 districts have less than 30% of children receiving an adequate diet, and 17 districts have more than 50% of stunted children. Furthermore, 12 districts have more than 50% of underweight children, and no district in India is close to achieving the SDG 2030 target of reducing stunted children to 6%.

The SPI 2022 also states that prevalence of anaemia is higher among children than in women in ADP districts. The average prevalence of anaemia among women in these districts is 61.20%, while among children, it is 69.65%. The performance on the prevalence of anaemia among women varies from 26.9% to 81.5%, with 93 out of 112 Aspirational Districts having more than 50% of anaemic women.

TABLE 2: CAUSES OF ANAEMIA			
Nutritional		**Non-nutritional**	
Iron deficiency	• Iron status ranges from deficiency with anaemia to deficiency without anaemia, normal status with varying stored iron, and iron overload. • Iron deficiency anaemia (IDA) is at the extreme lower end, causing negative impacts on cognitive performance, behaviour, growth in children, and immune status across all age groups. • Iron requirements vary for different groups, with higher	**Helminthic infestation**	• Helminths like hookworm and flukes cause chronic blood loss and iron loss in the body, leading to anaemia • A hookworm burden of 40-160 worms (depending on the host's iron status) is linked to iron deficiency anaemia (IDA).
		Malaria	• Malaria, particularly by Plasmodium falciparum and vivax, leads to anaemia by rupturing RBCs and

[4]An existing mechanism, for example, is the collaboration between Centre for Disease Control (CDC), USA with International Micronutrient Malnutrition Prevention and Control (IMMPaCt) program to focus on focuses on deficiencies of iron, vitamin A, iodine, folate, zinc, and vitamin D and works on micronutrient surveillance and research to fill critical data gaps.

[5] The Social Progress Index (SPI) is a comprehensive and holistic tool used to measure a country's social progress at both the national and sub-national levels. This index evaluates states and districts by considering 12 components that span three crucial dimensions of social progress.

[6] The Aspirational Districts Programme (ADP) was launched in 2018 to quickly and effectively transform some of the most under-developed districts across the country. These districts under this programme are characterized by poor socio-economic indicators and are ranked based on incremental progress across 49 Key Performance Indicators (KPIs).

	needs during childhood growth. • Lack of exclusive breastfeeding and un-supplemented milk diets can cause deficiency in infants. • Blood loss during menstruation and increased requirements during pregnancy and lactation may lead to poor iron stores in women due to traditional eating patterns.		suppressing RBC production. • Acute infection can result in decreased RBC production due to marrow hypoplasia. Plasmodium falciparum is the main cause of severe malaria in endemic regions. • Malarial anaemia poses significant risks of morbidity and mortality, especially in children and pregnant women infected with Plasmodium falciparum. • Malaria during pregnancy increases the risk of maternal anaemia, stillbirth, spontaneous abortion, low birth weight (LBW), and neonatal deaths.
Other micronutrient deficiencies	• Vitamin B12 is vital for RBC synthesis, and its deficiency can lead to megaloblastic anaemia. • Diets low in animal protein, common in India, along with malabsorption due to parasitic infections in the small intestine, may cause Vitamin B12 deficiency and anaemia. • Folic acid is essential for RBC formation, maturation, and cell growth and repair. • Folate deficiency reduces DNA synthesis, leading to	**Sickle cell disease and thalassemia**	• Sickle cell disease is an inherited disorder affecting haemoglobin, leading to recurrent haemolytic anaemia. • Thalassemia is a major haemoglobinopathy worldwide, caused by reduced or absent globin chain in haemoglobin. Approximately 10% of global thalassemia patients are from the Indian subcontinent, with 3.4% being carriers.
		Infections	• Chronic diseases like cancer, HIV/AIDS,

	impaired cell proliferation and intramedullary death of abnormal cells, resulting in shortened RBC lifespan and anaemia.		rheumatoid arthritis, Crohn's disease, and other chronic inflammatory conditions can disrupt RBC production, leading to chronic anaemia. • Kidney failure is another condition that can cause anaemia.
Source: (The National Guidelines for Control of Iron Deficiency Anaemia, 2013)			

Moreover, 67 ADP districts, which constitute over 50% of the total, have less than 12% of children receiving an adequate diet. Additionally, 82 out of 112 ADP districts have more than 30% of underweight children under five years. The challenges of child nutrition and anaemia persist in these regions, emphasizing the need for targeted interventions and improved healthcare strategies to address these issues effectively.

TABLE 3: FEW SELECT NFHS- 5 INDICATORS SPECIFIC TO NUTRITION STATUS AMONG INDIANS

Cohort characteristics	Age and other characteristics	NFHS-5 (2019-21)	NFHS-4 (2015-16)	Percentage change
BMI	Women	18.7	22.9	**-18%**
	Men	16.2	20.2	**-20%**
Iron folic consumption among mothers when they were pregnant	for 100 days or more	44.1	30.3	**46%**
	for 180 days or more	26	14.4	**81%**
Nutritional Status of Children under 5 years	stunted (height-for-age)	35.5	38.4	**-8%**
	wasted (weight-for-height)	19.3	21	**-8%**
	underweight (weight-for-age)	32.1	35.8	**-10%**
SOURCE: NFHS-5 (2019-21)				

India's National Family Health Survey 5 (NFHS 5) reveals some positive progress in specific nutritional status indicators, such as BMI and the consumption of iron folic acid supplements among pregnant women (refer to Table 1). However, it is concerning to observe that the incidence of anaemia has actually increased across all segments of society covered by the NFHS questionnaire during the period between NFHS 4 (2015-16) and NFHS 5 (2019-21). This rise in anaemia prevalence is evident among various population groups, including children, pregnant and non-pregnant women, and men (refer to Table 2). Despite improvements in other nutritional measures, this persistent and widespread increase in anaemia cases calls for targeted interventions to address this escalating health concern.

TABLE 4: PREVALENCE OF ANAEMIA: SELECT NFHS-5 INDICATORS				
Cohort characteristics	**Age and other characteristics**	NFHS-5 (2019-21)	NFHS-4 (2015-16)	**Percentage change**
Children	age **6-59 months**	67.1	58.6	15%
Women	*Non-pregnant* age **15-49 years**	57.2	53.2	8%
	Pregnant women **age 15-49 years**	52.2	50.4	4%
	age **15-19 years**	59.1	54.1	9%
	age **15-49 years**	52.2	50.4	4%
Men	age **15-19 years**	31.1	29.2	7%
	age **15-49 years**	25	22.7	10%
SOURCE: NFHS-5 (2019-21)				

The high incidence of anaemia in India, as revealed by the National Family Health Survey 5 (NFHS 5), reflects not only a poor diet but also prevalent micronutrient deficiencies. This data emphasizes the need for targeted interventions to address the escalating rates of anaemia in the country and underscores the importance of implementing comprehensive nutrition programs to combat malnutrition in all its forms.

Discovering micronutrient deficiencies and development of food fortification

The understanding of nutrition and its significance for human health has been ingrained throughout history. Nutrition can be classified as a public good due to its non-rivalrous nature, meaning one person's consumption doesn't limit its availability to others, and its non-excludable aspect, making it difficult to prevent people from benefiting. Moreover, nutrition's wide-ranging benefits, spanning across age, gender, and socioeconomic status, make it vital for growth, health, and disease prevention. Given its public good characteristics, government intervention becomes justified to ensure equitable access to nutrition.

This section will provide a concise account of contemporary recognition of how micronutrient deficiency emerged along with the solutions that emerged to resolve it focussing on food fortification at a global level. Thereafter, it will delve into the incidence of anaemia as a representative case to acknowledge the diverse factors contributing to it and the corresponding interventions. Overall, this section will highlight the evolving perspective on micronutrient deficiency and eventual inception of food fortification.

Setting Sail

A significant milestone in understanding micronutrient deficiency came with the pioneering work of James Lind in 1753. Lind conducted clinical trials on sailors aboard the HMS Salisbury, leading to his famous report on scurvy. His findings eventually led to the routine issuance of lime juice to British sailors, who became known as "limeys." (Tulchinsky, 2010)

Over the next century, scientific knowledge advanced, highlighting the importance of essential nutrients like iron and iodine for maintaining health. In the 1880s, Kanehiro Takaki demonstrated how dietary changes eradicated beriberi among Japanese sailors. Similarly, Christiaan Eijkman's research in Java linked dietary factors to chicken polyneuritis and neuropathy in humans. (Tulchinsky, 2010)

The term "vitamins" was coined in 1912 by Casimir Funk, leading to significant progress in scientific and public health understanding of these essential nutrients. During the early decades of the 20th century, an epidemic of pellagra in the southern US was investigated by Joseph Goldberger of the U.S. Public Health Service (USPHS), and it was determined to be a nutritional deficit rather than an infectious disease. This led to fortifying flour with B vitamins in many southern states, effectively combating the epidemic. (Tulchinsky, 2010)

In 1917, investigations into goitre among recruits to the U.S. Army led to the conclusion that iodizing salt was the best approach to address the problem. Switzerland and the United States adopted the strategy of fortifying salt with iodine in the 1920s, a measure later recognized by the World Health Organization (WHO) as a globally significant public health initiative. (Tulchinsky, 2010)

Importance of measuring Anaemia

Anaemia, a condition characterized by a deficiency of red blood cells, is a prevalent health issue with significant global implications. The primary cause of anaemia is insufficient iron, a crucial nutrient essential for the formation of haemoglobin, the protein responsible for carrying oxygen in the blood. In addition to iron deficiency, anaemia can also result from deficiencies in other essential nutrients such as vitamin B12, vitamin A, folate, and zinc, all of which play vital roles in red blood cell production and overall health.

The discovery of the link between pernicious anaemia and vitamin B12 deficiency by Gorge Minot and his colleagues in the 1920s marked a groundbreaking advancement in medical science. This important finding not only provided valuable insights into the pathophysiology of anaemia but also laid the foundation for early cytotoxic cancer treatments. Their pioneering work earned them the prestigious Nobel Prize in 1934 and had a profound impact on the understanding and management of anaemia and related conditions. (Mukherjee, 2011)

Around the same time in Bombay, impoverished workers in English-owned cloth mills faced acute malnutrition and lacked access to adequate medical care. Anaemia, particularly prevalent among women who had recently given birth, was evident through blood tests. In 1928, English physician Lucy Wills conducted pioneering research to investigate this enigmatic anaemia in Bombay. She discovered that neither Minot's dietary concoction nor vitamin B12 could cure it. Her groundbreaking discovery came in the form of a remedy found in Marmite, a popular spread in England and Australia, which contained a substance she referred to as the "Wills factor." This mysterious substance was later identified as folic acid, a vitamin-like nutrient present in fruits and vegetables. Folic acid is essential for DNA synthesis and cell division, and its deficiency can lead to a halt in blood cell production, resulting in anaemia, as observed in individuals lacking vegetables in their diet in Bombay. (Mukherjee, 2011)

Lucy Wills' remarkable work shed light on the importance of micronutrients in combating anaemia and highlighted the significance of a balanced diet for overall health. Her findings have had far-reaching implications in the field of nutrition and have underscored the critical role of essential vitamins and minerals in preventing and treating anaemia.

The expansion of food fortification as a public health policy

In 1941, President Franklin D. Roosevelt's nutrition conference in the White House recommended fortifying basic foods to prevent silent malnutrition. These recommendations were implemented across the US, Great Britain, and Canada. However, in the post-war period, enforcement of vitamin fortification decreased in Canada and Britain, as clinical rickets appeared to have disappeared. (Tulchinsky, 2010)

During the 1990s, the issue of folic acid and its role in preventing neural tube birth defects gained prominence in public health policy. Although providing supplements to all women capable of becoming pregnant achieved limited compliance, the U.S. Food and Drug Administration mandated the addition of folic acid to "enriched flour." Canada, Chile, and other countries also adopted mandatory fortification of flour with folic acid as a common approach. (Tulchinsky, 2010)

BOX 2

#Future Fortified Global Summit

The September 2015 #Future Fortified Global Summit on Food Fortification in Arusha, Tanzania, addressed achievements and challenges of large-scale food fortification in LMIC. It aimed to build a consensus among global stakeholders for scaling up fortification in alignment with the Sustainable Development Goals. The resulting "Arusha Statement on Food Fortification" outlined commitments to tackle monitoring, compliance, and equity challenges. (Osendarp, et al., 2018)

It highlighted five critical areas for immediate progress:

1. **modest but new investments by governments and donors to ensure technical support and capacity, compliance, and leveraging co-investment by the private sector**
2. **improving the oversight and enforcement of food fortification standards and legislation**
3. **generating more evidence to demonstrate impact and further guide fortification policy and program design**
4. **more transparent accountability and global reporting**
5. **continuing advocacy for greater attention to fortification by governments**

Proper nutrition is not just about satisfying hunger; it is a fundamental aspect of a human being's everyday life that plays a crucial role in their overall well-being and quality of life. Addressing malnutrition comprehensively and promoting healthy and sustainable diets are essential steps in ensuring the health and prosperity of individuals and communities worldwide.

A case for rice fortification as a remedy to micronutrient malnutrition

In an economy, the food system works in conjunction with various other systems, such as health, water, sanitation, education, and social protection, to ensure that every stage of a human's life is supplied with a safe and nutritious diet. Food fortification, a process of enhancing the nutritional quality of commonly consumed foods by adding vitamins and minerals, requires a vehicle with broad reach and affordability post fortification (UNICEF, 2020).

Among staple foods, rice holds a prominent position globally, along with wheat and maize, making up 94% of total cereal consumption (Guideline: fortification of rice with vitamins and minerals as a public health strategy, 2018). Due to its widespread consumption, high acceptance, and extensive availability, rice presents itself as a promising candidate for large-scale fortification initiatives.

Remarkably, rice contributes significantly to caloric intake worldwide, accounting for 30% of total calories in an average diet and surpassing 70% in low-income countries, according to the WHO report "Guideline: fortification of rice with vitamins and minerals as a public health strategy" in 2018. This widespread consumption of rice offers a promising opportunity to effectively deliver essential micronutrients to a large number of individuals.

However, the rice milling process, particularly in the production of white rice, results in the removal of nutrient-rich bran layers, leading to significant losses of essential micronutrients like B-group vitamins and vitamin E. Fortifying rice with vitamins and minerals can effectively address these nutrient depletions, elevating the overall nutritional value of rice and ensuring that populations access critical micronutrients, even when consuming milled rice.

BOX 3

How is rice fortified?

At present, fortified rice is produced using extrusion technology, which involves milling rice into powder and blending it with a premix of essential vitamins and minerals tailored to meet local nutrient needs. The mixture is then extruded to create fortified rice kernels that are combined with regular rice at a ratio of 1:50 to 1:200, weight basis, resulting in fortified rice with the same aroma, taste, and texture as traditional rice. Extrusion is the preferred method due to its stability in preserving micronutrients during processing, storage, washing, and cooking, as well as its cost-effectiveness.

The primary objective of rice fortification with vitamins and minerals is to improve the nutritional status of populations, especially in regions where rice is a predominant dietary staple, while simultaneously reducing the prevalence of micronutrient deficiencies such as thiamine, niacin, vitamin B6, and vitamin E (Guideline: fortification of rice with vitamins and minerals as a public health strategy, 2018). Given the prevailing circumstances, rice fortification emerges as a favourable approach to tackle nutritional deficiencies and enhance health, particularly among vulnerable population segments. Notably, at the Copenhagen Consensus in 2012, fortification with micronutrients was ranked by a group of Nobel Laureates as one of the most cost-effective investments with significant benefits that could be made.

Establishing effectiveness of rice fortification

The Cochrane Systematic Review "Fortification of rice with vitamins and minerals for addressing micronutrient malnutrition" aimed to investigate in 2019 the effects of rice fortification with vitamins and minerals on nutritional status in the general population aged two years and older, particularly in countries where micronutrient deficiencies are prevalent.

The systematic review included 17 studies involving a total of 10,483 participants from diverse countries, including Bangladesh, Brazil, Burundi, Cambodia, India, Indonesia, Mexico, the Philippines, Thailand, and the USA. Out of these, 12 were randomized controlled trials (RCTs) with 2,238 participants, primarily involving children, and two studies specifically targeted non-pregnant and non-lactating women. In addition to iron, some studies included vitamin A, zinc, or folic acid as fortifying agents, either alone or in combination. To complement the data, five non-randomized studies were analysed, providing valuable insights into the implementation and impact of fortification programs.

The findings of the Cochrane Review suggest that fortifying rice with iron alone or in combination with other micronutrients may have little or no effect on the risk of anaemia. However, the intervention appears to reduce the risk of iron deficiency, which is a positive outcome. Additionally, the analysis indicates that rice fortification may lead to an increase in mean haemoglobin concentrations, which serves as a biomarker for anaemia. This suggests that while rice fortification might not fully prevent anaemia, it can contribute to an improvement in iron status, leading to potential health benefits.

Furthermore, when rice is fortified with vitamin A, the results indicate that it may have little impact on haemoglobin and serum retinol concentrations, another biomarker for vitamin A nutrition. However, it is important to note that the evidence regarding the effect of vitamin A fortification is of low certainty, highlighting the need for further research in this area.

Despite the potential benefits of rice fortification, the review also underscores certain limitations and uncertainties. The overall certainty of the evidence was rated as low to very low, indicating the need for caution in interpreting the findings. Additionally, the studies primarily used iron as the fortifying agent, making it difficult to assess the individual effects of isolated nutrients. More research is needed to evaluate the impact of fortified rice with specific micronutrients on different health outcomes and to gain a comprehensive understanding of their long-term effects.

The review identified that the studies had varying degrees of risk of bias. While some studies had robust randomization procedures and low attrition rates, others lacked clear descriptions of sequence generation and allocation concealment. To enhance the reliability of future research, it is crucial for studies to adhere to rigorous methodological standards and ensure transparency in reporting.

It is important to look at studies on fortification done on Indian population specifically as well. Syed Zameer Hussain, Baljit Singh and A.H.Rather conducted a study "Efficacy of Micronutrient fortified Extruded Rice in Improving the Iron and Vitamin A status in Indian Schoolchildren" in 2014. The study involved 222 children aged 5-8 years who were attending a subsidized lunch feeding program and were depleted in iron and vitamin A. It was a part of the abovementioned Cochran Review as well. The researchers conducted efficacy studies over six months, where they provided the children with micronutrient-fortified rice. The results showed a significant increase in haemoglobin and serum ferritin levels, indicating an improvement in iron status. Additionally, there was a significant decrease in total iron binding capacity, further supporting the positive impact of the fortified rice. The rice fortified with both iron and either vitamin A or beta-carotene had the most pronounced effects on the children's nutritional status. However, the sensory evaluation revealed that beta-carotene fortified rice did not match the white colour of natural rice. Despite this, the cost analysis indicated that fortification had minimal impact on rice consumption. The researchers concluded that providing micronutrient-fortified rice in school feeding programs can effectively reduce iron deficiency, iron-deficiency anaemia, and vitamin A deficiency in developing countries. Moreover, the extruded micronutrient-fortified rice, except for beta-carotene fortified rice, was well-received due to its excellent sensory characteristics.

A year 2006 study by Diego Moretti, Tung-Ching Lee, Michael B. Zimmermann, Jeannette Nuessli, Richard F. Hurrell titled "Development and Evaluation of Iron-fortified Extruded Rice Grains" aimed to develop iron-fortified rice that tastes and feels like natural rice, using iron compounds that are easily absorbed by the body. They tested different iron compounds like ferrous sulfate, (Sodium iron EDTA) NaFeEDTA, ferric pyrophosphate of various particle sizes, electrolytic iron, and encapsulated iron. The production method involved blending extruded rice grains with different iron levels into natural rice. They evaluated the colour and texture of the extruded grains, measured iron loss during rinsing, and compared the taste of fortified and unfortified rice through triangle tests. The results showed that micronized ferric pyrophosphate had colour scores similar to natural rice, and the cooked extruded grains had comparable texture with less than 3% iron loss during rinsing. Fortification with other compounds led to significant colour changes. However, rice fortified with micronized ferric pyrophosphate closely resembled unfortified rice in both raw and cooked forms in the triangle tests. In conclusion, using micronized ferric pyrophosphate allows the production of iron-fortified extruded rice with excellent sensory characteristics and potentially high bioavailability. According to the Indian standards outlined in The Food Safety and Standards (Fortification of Foods) Regulations, 2018, Ferric pyrophosphate is the approved compound or nutrient for fortifying rice with iron, as supported by the aforementioned study.

A 2014 study titled "Micronized ferric pyrophosphate supplied through extruded rice kernels improves body iron stores in children: a double-blind, randomized, placebo-controlled midday meal feeding trial in Indian schoolchildren" investigated if adding micronized ferric pyrophosphate (MFPP) to rice meals can improve iron levels in Indian schoolchildren.

In this study, researchers investigated the effects of fortified rice on the health of schoolchildren. They found that consuming rice fortified with micronized ferric pyrophosphate (MFPP) along with regular rice for 8 months significantly improved the children's iron levels and reduced iron deficiency. Both the fortified rice group and the unfortified rice group showed a significant increase in mean haemoglobin levels and a decrease in anaemia prevalence. However, the additional impact of the fortified rice on haemoglobin status was not distinct from the improvement seen in the unfortified rice group, suggesting other factors may have influenced haemoglobin levels.

The fortified rice group showed better improvement in body iron stores and iron deficiency but did not have a significant effect on reducing iron-deficiency anaemia or improving haemoglobin levels compared to the unfortified rice group. This finding is in line with the three studies aforementioned. One possible reason for this could be that the small-particle-size MFPP used in the fortified rice may not be absorbed as effectively. Moreover, only a small percentage of children in the study had iron-deficiency anaemia, and there may have been concurrent deficiencies in other micronutrients like vitamin C, vitamin A, riboflavin, folic acid, and vitamin B-12, limiting iron absorption.

The study also found that the fortified rice had similar sensory qualities to unfortified rice when cooked. While the bioavailability of iron from the fortified rice was lower than from unfortified rice, providing 21 mg of iron through the fortified rice significantly improved the children's iron stores and reduced iron deficiency. Further large-scale community-based studies are needed to confirm the effectiveness of this fortified rice approach, especially in vulnerable population groups like preschool children, adolescent girls, pregnant women, and lactating mothers. The study highlights the potential of using fortified rice in food security programs to address micronutrient deficiencies in developing countries and improve health outcomes in vulnerable populations.

The study "Multiple Micronutrient-Fortified Rice Affects Physical Performance and Plasma Vitamin B-12 and Homocysteine Concentrations of Indian School Children" in 2014 aimed to assess the effects of fortified rice on the health of children aged 5-8 years attending a subsidized lunch feeding program. The researchers conducted efficacy studies over a period of six months and analysed the impact of fortified rice on various health parameters. This study is important as it included nutrients other than iron in its analysis as well.

The results of the study showed significant improvements in vitamin B-12 status and physical endurance among the children who consumed fortified rice. This was indicated by a reduction in homocysteine levels, a surrogate marker for vitamin B-12 status, and enhanced physical performance among the children. The fortified rice also led to a decrease in the prevalence of anaemia in the low-iron group, attributed to increased vitamin B-12 concentration and improved vitamin A status. However, the fortified rice did not have a significant effect on zinc, retinol, or cognitive performance of the children. The study also highlighted the need for further research in areas with more significant micronutrient deficiencies is warranted to fully understand the effects of fortified rice and its potential role in addressing malnutrition in developing countries.

BOX 4

Summary of research studies

The major findings of studies elucidated above can be summarised plainly as follows:

- The findings suggest that rice fortification with iron alone or in combination with other micronutrients may have little or no effect on the risk of anaemia but can **reduce the risk of iron deficiency and increase mean haemoglobin concentrations.**
- Fortifying rice with vitamin A may have little impact on haemoglobin and serum retinol concentrations, but the evidence on the effect of vitamin A fortification is of low certainty, requiring more research.
- Additional studies on Indian populations specifically show **that micronutrient-fortified extruded rice can effectively improve iron and vitamin A status in schoolchildren attending subsidized lunch feeding programs.**
- Studies using micronized ferric pyrophosphate in fortified rice have shown promising results in terms of sensory characteristics and potentially high bioavailability of iron.
- Further research is needed to assess the impact of fortified rice on different health outcomes and its long-term effects.
- **Fortified rice shows potential in addressing micronutrient deficiencies in developing countries and improving health outcomes,** but large-scale community-based studies are necessary to confirm its effectiveness, especially in vulnerable population groups.
- The fortified rice approach can help reduce iron deficiency and improve physical performance and vitamin B-12 status in schoolchildren. However, more research is needed to fully understand the effects of fortified rice on different micronutrients and its role in addressing malnutrition.

The advent of Large-scale Staple Food Fortification (LSSF) in India

Osendarp, et al., (2018) define large-scale food fortification as "the production capacity (more than 50 metric tons/d), often a prerequisite for mass fortification, which refers to the reach of a fortified product".

Food fortification has a rich history, dating back almost a century, and has proven effective in addressing deficiencies in various countries. This process involves adding one or more micronutrients to commonly consumed foods like grains, salt, condiments, sugar, or edible oil at the central level or during production. Typically, government sectors mandate and regulate fortification based on evidence of micronutrient deficiencies or potential benefits to specific populations (Osendarp, et al., 2018). Presently, over 130 countries mandate iodine fortification in salt, while 80 countries fortify cereal grains such as wheat, rice, or maize. Additionally, some countries fortify milk and edible oils

Successes, limitations and insights

India's initiatives for food fortification primarily targeted supply-side challenges. Historically, the emphasis was on addressing deficiencies in iodine, Vitamin A, and iron, which are commonly lacking in Indian diets. Notably, the fortification of Vanaspati with Vitamin A, dating back to 1953, stands as one of the earliest successful interventions in this regard.

In the 1940s, vanaspati lacked vitamin A, unlike ghee, due to the absence of vitamin A in the vegetable oils used for its production. The addition of vitamin A from marine oils was avoided to respect consumer socio-religious beliefs. However, in 1950, synthetic vitamin A from lemon grass oil emerged, prompting the Ghee Adulteration Committee and the Nutrition Advisory Committee (November 1952) to recommend fortification of vanaspati with synthetic vitamin A to enhance its nutritional value and match ghee. In 1951, the Vegetable Oil Products Controller mandated manufacturers to declare vitamin content on the label if claiming vitaminization of vanaspati. (Food Fortification to End Micronutrient Malnutrition: State of the Art, 1997)

Mandatory iodine fortification of salt in India began in 1962, leading to significant public health achievements. (Journey of Food Fortification: Fighting Malnutrition Improving Lives, 2016). As per the recommendations of the Central Council of Health in 1984, the government decided to iodate all edible salt by 1992, with the program initiating in April 1986 in a phased manner. Currently, the country produces 65 lakh metric tons of iodated salt annually. Household consumption of adequately iodated salt has risen from 51.1% (NFHS III report 2005-06) to 71.1% (CES report, 2009).

Yet, even post 4th five-year plan (1969–1974), poverty and malnutrition continued to persist in India. The plan relied on economic growth and self-reliance policies, hoping that benefits would trickle down to all levels of society, but this proved insufficient. The 5th year plan then took a direct approach to address poverty, unemployment, and malnutrition, introducing interventionist strategies to increase purchasing power for the poor and expand the social safety net. (Duggal, et al., 2022)

BOX 5

Challenges in overcoming malnutrition

Combating malnutrition is a complex task. Access to nutritious food is increasingly affected by various factors known as demand-side constraints and supply-side constraints.

Demand-side constraints: These **include income poverty, limited education, cultural influences, food insecurity, and gender inequality**. Poverty makes it hard for people to afford nutritious food, and lack of education leads to a lack of awareness about healthy choices. Cultural norms influence what people eat, and food insecurity makes it difficult to consistently access safe and nutritious food. Gender inequality adds to the challenges, especially for women and girls.

Supply-side constraints: Supply-side constraints pose challenges in addressing malnutrition, even when there is a demand for nutritious foods. These constraints **encompass inadequate food production, inefficient distribution, poor quality, and high prices.** Inadequate food production can result from factors like climate change, conflict, or natural disasters, leading to shortages and malnutrition, particularly in high-population growth regions. Inefficient distribution can create imbalances, causing difficulties in accessing nutritious foods even when available. Poor food quality, due to spoilage, contamination, or adulteration, can compromise safety and contribute to malnutrition. Additionally, high food prices can hinder access for those living in poverty, making nutritious foods less affordable.

The National Nutrition Policy of 1993 recognized nutrition as a multi-sectoral issue that required action at various levels. It emphasized fortification of essential foods as a crucial short-term policy instrument for direct intervention. The policy highlighted the need to identify a suitable vehicle for marketing and distributing fortified foods. Salt, being one of the earliest food items to be fortified and widely distributed through markets and government programs, had a highly decentralized marketing process (National Nutrition Policy, 1993). To ensure quality control and broader coverage for the target population, it was deemed necessary to identify a vehicle with greater reach and control over the distributed food items. Additionally, it made a case for intensifying research in iron fortification in rice (and other cereals).

Rice Fortification in India: Unveiling and Progress

In India, rice production has seen steady growth over the years. It serves as the primary sustenance for approximately 65% of the population, providing 50% of their total energy intake. Fortifying rice with vitamins and minerals enhances its nutritional value, compensating for nutrient losses during milling and polishing. Rice plays a crucial role in various government safety net programs, such as the PM Poshan (earlier Midday Meal Scheme), Integrated Child Development Services (ICDS), and the Public Distribution System (PDS).

Thus, rice fortification holds great promise to bridge nutritional gaps, particularly since it serves as the staple food for a large section of the population, including vulnerable and marginalized groups benefitting from government safety net programs. Presently, the state food and civil supplies departments collaborate with rice millers to ensure regular rice supply for distribution through social safety net schemes.

Key Consultations and Meetings Held on rice fortification

BOX 6

Rice fortification elsewhere across the globe

Out of the annual **222 million metric tons of industrially milled rice globally, less than 1%** undergoes essential vitamin and mineral fortification. Presently, eight countries (**Costa Rica, Nicaragua, Panama, Venezuela, India, Papua New Guinea, the Philippines, and the United States**) have implemented mandatory rice fortification programs. Additionally, **Brazil, Colombia, and the Dominican Republic** have large-scale non-mandatory rice fortification initiatives.

Japan has been fortifying grains added to rice before cooking for several decades, with fortified products available since 1981. Similarly, **Costa Rica** has mandated rice fortification since 2001, incorporating folic acid, vitamin B1, vitamin B3, vitamin B12, vitamin E, selenium, and zinc. This successful food fortification approach is evident in Costa Rica's reduction of neural tube defects (NTDs), attributed to experiences with fortification, a centralized rice industry, government leadership, and private sector support. (Osendarp, et al., 2018).

Between October 2016 and October 2017, several significant consultations and meetings were conducted to prioritize rice fortification in India. National Summits and Consultations involved high-level officials, such as the Honourable Union Minister of Consumer Affairs, Food and Public Distribution, Shri Ram Vilas Paswan, and Honourable Union Minister of State, Smt. Anupriya Patel, who emphasized the importance of implementing the comprehensive regulations on food fortification. Special meetings with key government ministries, including the Ministry of Health and Family Welfare, Ministry of Women and Child Development, and others, aligned their efforts with fortification goals. (Large Scale Food Fortification in India: The Journey So Far and Road Ahead, 2017)

During this period, 5 Zonal Consultations were jointly organized by the Ministry of Women and Child Development and FSSAI across different regions, aimed at implementing large-scale food fortification tailored to the specific needs of each zone. State-level meetings were also held to discuss the inclusion of fortified staples in the Public Distribution System (PDS) and various other government safety net programs. Notably, discussions took place with government officials from West Bengal, Delhi, Assam, Karnataka, Punjab, Rajasthan, Haryana, and Madhya Pradesh, among others. (Large Scale Food Fortification in India: The Journey So Far and Road Ahead, 2017)

Technical consultations emphasized strengthening the technical aspects of food fortification, including premix supply and quality. These efforts were carried out in collaboration with organizations like GAIN (Global Alliance for Improved Nutrition) and IIHMR (Indian Institute of Health Management Research). To disseminate India's experience in food fortification internationally, delegations were sent to Sri Lanka and Myanmar to share key learnings in rice fortification. Additionally, Sri Lankan and Myanmar delegations visited India to gain insights into successful implementation strategies. (Large Scale Food Fortification in India: The Journey So Far and Road Ahead, 2017)

Throughout this period, these consultations, meetings, and technical interactions fostered the prioritization of rice fortification in India and served as crucial steps towards addressing nutritional gaps and improving the health of vulnerable populations.

Towards the launch of the pilot scheme

Starting in 2008 and spanning over a decade, FSSAI had noted compelling evidence (including up to 1 million children in pilot studies) showcasing the effectiveness of fortified rice in improving micronutrient status, reducing anaemia, and increasing Hb levels, iron stores, vitamin B12, and zinc levels. It firmly believed that rice fortification held immense potential in India, given its status as the staple food for 65% of the population, especially benefiting vulnerable groups like women and children through safety net programs like ICDS, PDS, and MDM.

The Department of Food & Public Distribution, in collaboration with the Poshan Abhiyaan, aimed to promote nutrition security by exploring the feasibility of fortifying foodgrains distributed through PDS directly to households and targeted welfare schemes (FFRC, n.d.). In 2016, rice fortification standards were established and later gazetted in 2018, prompting several states to initiate the scaling up of rice fortification through various safety net programs. The Government of India had integrated staple food fortification, including rice fortification, into the National Nutrition Mission (Poshan Abhiyan) as a complementary approach to combat anaemia and under-nutrition. The "Anaemia Mukt Bharat" initiative under Poshan Abhiyan further emphasized the importance of fortified foods, deworming, food supplementation, and dietary diversification in public health programs. (FFRC, n.d.)

In 2019, the Department of Food & Public Distribution had launched a pilot scheme to fortify rice in 15 aspirational districts through the Public Distribution System program. The success of these pilots eventually led to a nationwide scale-up in 2022, making rice fortification mandatory in all government rice supply programs[7]. *(More on this in the subsection "Phased unfolding of rice fortification" within this section)*

BOX 7

Unit cost of fortifying rice

The cost of fortification depends on various factors, such as the rice industry's structure, supply chain complexity, policies, and program scale. A low-cost extruder may range from 35 to 40 lakhs INR, while a high-quality one can cost up to 13.5 crore INR. Additional costs for fortified rice vary from 1% to 10% of the retail price, with an approximate additional cost of INR 0.45 per kg to the consumer, depending on the added nutrients. As production and distribution expand, economies of scale are expected to reduce costs, making rice fortification an effective solution. (FFRC, n.d.)

Establishing regulations and regulator

In October 2016, the Food Safety and Standards Authority of India (FSSAI) organized a National Summit on Food Fortification, bringing together various stakeholders from government, industry, food businesses, development partners, scientists, and academia. The summit led to the formulation of standards for fortifying key staples like oil, salt, milk, wheat

[7] Although, in the open market rice fortification remains voluntary, there are still few brands of available. FSSAI website lists three brands of fortified rice which are available in the open market. These are *Asbah Siver, Daawat Sehat Mogra*, and *Sri Lohita*. For additional information see: https://fortification.fssai.gov.in/commodity?commodity=fortified-rice

flour, and rice, as well as the launch of a logo for fortified foods, thus firmly establishing fortification on the national agenda (FFRC, n.d.). Since then, voluntary fortification efforts have commenced for five staples: wheat flour, edible oil, double fortified salt, milk, and rice.

These efforts lead to Food Safety and Standards (Fortification of Foods) Regulations, 2018 which laid down the guidelines for adding essential micronutrients to fortified food products. Manufacturers of such fortified foods are now obligated to provide a quality assurance undertaking, ensuring the adherence to prescribed standards. The packaging and labelling of these fortified foods must clearly indicate the added food fortificant, along with the +F logo and the tagline "Sampoorna Poshan Swasth Jeevan," signifying complete nutrition. (FFRC, n.d.)

BOX 8
Leveraging social assistance programs for fortified rice distribution

India's social assistance programs cater to the most impoverished and nutritionally vulnerable segments of society. Within these programs, three initiatives already distributing rice offer an opportunity to enhance participants' nutrition through the implementation of food fortification strategies. These programs include:

1. **Public Distribution System (PDS):** Households receive ration cards to redeem for rice at fair-price shops, targeting approximately **800 million people.**
2. **PM Poshan School Lunch Program (previously Midday Meal Program):** Schoolchildren aged 6-14 years (grades 1 to 8) are served hot midday meals, totalling **118 million beneficiaries**.
3. **Integrated Child Development Services (ICDS):** Pregnant and lactating women, children aged 6-36 months, and children aged 3-6 years receive take-home rations, while older children are provided with hot cooked meals at mother-child health and nutrition centres. This program serves around **110 million people.**

Implementing fortified rice distribution within these social assistance programs presents a promising strategy to combat micronutrient deficiencies on a large scale in India. (The Proof Is In The Pilot: 9 Insights From India's Rice Fortification Pilot to-Scale Approach, 2022)

Additionally, the packaging and labelling must comply with the requirements specified in the Food Safety and Standards (Packaging and Labelling) Regulations, 2011 (Large Scale Food Fortification in India: The Journey So Far and Road Ahead, 2017). The regulations also set standards (in terms of the specific nutrients and their range level per kilogram) for fortification of five staple foods: Salt, Oil, Milk, Atta, Maida and Rice.

FSSAI established the 'Food Fortification Resource Centre' (FFRC) as a nodal point, providing technical and implementation support, creating awareness among consumers about nutrition, food safety, and fortification in order to support and align stakeholders (Large Scale Food Fortification in India: The Journey So Far and Road Ahead, 2017). The FFRC is a dedicated platform that encourages and facilitates large-scale food fortification throughout India. It served as a platform, offering guidance on standards, food safety, technology, premix and equipment procurement and manufacturing, quality assurance, and quality control for fortification. It provided all information pertaining to fortification of food, for example, scientific evidence, latest technology, national and international experiences, government circulars and success stories. The centre's approach is to motivate and support the food industry in embracing fortification as a standard practice.

Phased unfolding of rice fortification

The global nutrition crisis and its impact on health, economies, and the environment have prompted action worldwide. 2021 was declared the Nutrition Year of Action, leading to significant commitments at the Tokyo Nutrition for Growth (N4G) Summit.

In India, a major step was taken by announcing the mandatory fortification of rice in all social safety net schemes by 2024 (Ministry of Consumer Affairs, One Year of Announcement of Rice Fortification, 2022). The programme cost of Rs. 2700 Cr. Per annum will be borne by the central government till its completion in June 2024. The announcement, made on the 75th Independence Day by the Prime Minister, has accelerated efforts to strengthen the ecosystem for rice fortification.

The cumulative annual Fortified Rice Kernel (FRK) manufacturing capacity has increased more than 18 folds from 0.9 LMT (34 FRK Manufacturing) in August 2021to 17 LMT (More than 400 FRK manufacturers), and measures for standardization and quality control are being implemented to ensure the effectiveness of the intervention (Kumar & Shekhar, 2021). This initiative was preceded by completion of Centrally Sponsored Pilot Scheme on "Fortification of Rice & its Distribution under Public Distribution System" This pilot scheme had a duration of three years, starting from 2019-20, with a total budget of Rs. 174.64 Crore. The focus of the scheme was on 15 districts across 15 states, with a preference for one district per state. (Ministry of Consumer Affairs, One Year of Announcement of Rice Fortification, 2022)

The Government of India has undertaken a comprehensive initiative to supply Fortified Rice in every Social Safety Net Scheme across the country by 2024. This ambitious endeavour is being executed in a phased manner, and significant progress has been achieved in the last two years. Let's delve into the key phases and developments:

- Phase-I: During the fiscal year 2021-2022, the initiative commenced by covering Integrated Child Development Services (ICDS) and the Prime Minister's POSHAN Abhiyan (PM POSHAN). In this initial phase, nearly 17.51 LMT (Lakh Metric Tons) of Fortified Rice was successfully distributed in various States and Union Territories.
- Phase-II: Building upon the success of Phase-I, the program expanded its scope to include the Targeted Public Distribution System (TPDS) in 27 States and Union Territories. Approximately 105 LMT of Fortified Rice was lifted for distribution through TPDS during this phase. Additionally, about 29 LMT of Fortified Rice was procured and distributed for ICDS and PM POSHAN, bringing the total Fortified Rice lifted to approximately 134 LMT during the financial year 2022-2023.
- Phase-III: The Department of Food and Public Distribution (DoFPD) is now fully committed to completing the coverage of all remaining districts, except those primarily consuming wheat, before the targeted date of March 2024. This final phase aims to ensure the availability of Fortified Rice in all relevant social safety net schemes across the entire nation, further enhancing the nutritional security of the population.

TABLE 5: OVERVIEW OF PHASED IMPLEMENTATION OF RICE FORTIFICATION IN INDIA					
Particulars	Details	PHASES			
		Pilot Scheme	Phase 1	Phase 2	Phase 3
Duration/ time of completion		2019-20	Till March 2022	The target date of completion was set as March 2023 but targets were achieved by 27 September, 2022, well ahead of time.	Commenced on 1 April, 2023 with the aim to achieve the targets by September 2023.
Coverage		15 Aspirational districts (later revised to 11)	Covering ICDS and PM POSHAN	Phase I + TPDS and OWS in all Aspirational and High Burden Districts on stunting (total 291 districts	Phase II+ covering the remaining districts of the country (except wheat consuming districts)
Proposed/Incurred Cost		174.64 Cr	266.91 Cr	1323.38 Cr	2679.47 Cr
Cost Borne by			Ministry of Women and Child Development & Department of School Education and Literacy respectively for the financial year 2021-22	Cost covered as a part of food subsidy bill of Department of Food & Public Distribution	Cost covered as a part of food subsidy bill of Department of Food & Public Distribution
Achievements		17.51 LMT of fortified rice have been lifted by States/UTs for distribution under ICDS and PM POSHAN	Phase-I covered ICDS and PM POSHAN. It was implemented during 2021-22 and nearly 17.51 LMT had been distributed in the States/UTs.	• Phase II of the Rice Fortification was completed well ahead of target of 31st March, 2023 by covering all the total of 269 districts in 27 states targeted rice consuming districts. • 105 LMT of Fortified Rice was lifted by Phase II targeted 27 States/UTs for PDS distribution.	

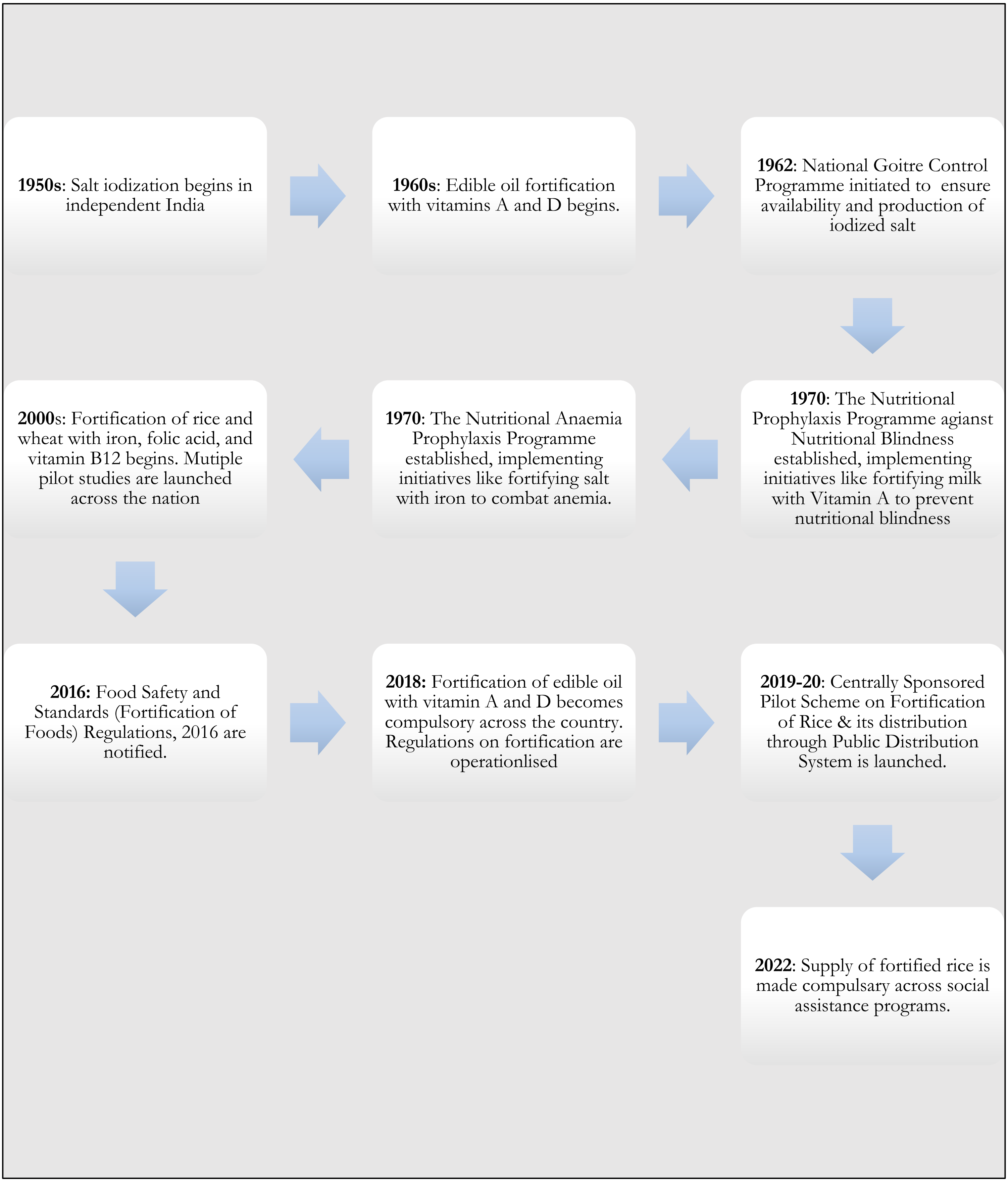
				• 29 LMT was lifted by the States/UTs under ICDS and PM POSHAN in Phase II. • Thus, a total of about 134 LMT fortified rice lifted in the FY 2022-23.	
Capacity	No. of Mills		2690 mills *(by August 2021)*	18227 mills *(by March 2023)*	
	Blending Capacity		3.67 LMT *(in August 2021)*	156 LMT *(in March 2023)*	
	No. of FRK Manufacturers		34 *(by August 2021)*	400 *(by April 2023)*	
	Annual Fortified Rice Kernel (FRK) manufacturing capacity		0.9 LMT	17 LMT	
NABL accredited Labs for testing of fortificants			20 *(by August 2021)*	48 *(by April 2023)*	
Source: (Ministry of Consumer Affairs, One Year of Announcement of Rice Fortification, 2022); (Ministry of Consumer Affairs, 269 districts in 27 states distributing Fortified Rice under Targeted Public Distribution System, 2023); (Ministry of Consumer Affairs, 92.77 LMT of fortified rice lifted in Phase II under TPDS for Aspirational and High Burden Districts, 2023); (Administrative approval for Supply of Fortified Rice, 2022)					

The successful implementation of these phases reflects the government's dedication to improving the nutritional quality of essential food supplies and uplifting the health and well-being of its citizens. The Fortified Rice initiative is poised to have a far-reaching impact on public health and nutrition, contributing significantly to the nation's overall well-being and development.

Additionally, the number of rice mills having blending infrastructure has increased from 2690 to 18227 from August 2021 to March 2023, significantly increasing monthly production capacity. This fortification program plays a crucial role in addressing nutritional deficiencies and has gained support from various stakeholders. Educational campaigns are underway to raise awareness about the nutritional benefits of fortified rice, contributing to nutritional security and combating malnutrition and anaemia in the country.

Currently, the Food Safety and Standards Authority of India (FSSAI) is working on standardizing FRK and facilitating the establishment of more NABL accredited labs and Bureau of Indian Standards Standardization of Extruders/Blenders to ensure quality.

DIAGRAM 1: UNFOLDING OF RICE FORTIFICATION IN INDIA: A BRIEF TIMELINE



Conclusion

Health constitutes one-third weight in the India national MPI[8] in line with global MPI. Nutrition as an indicator lies within the dimension of health hold half of the dimension's weight and constitutes one-sixth of the total weight in the constitution of the whole India's MPI. It underscores the role nutrition plays in combating multidimensional poverty and overall wellbeing of a population. In terms of percentage of deprivation among the population, the level of Nutrition has improved from 37.6% in 2015-16 to 31.52% in 2019-20 (National Multidimensional Poverty Index (MPI): A Progress Review 2023, 2023). It implies that level of nutrition has improved by almost 16% in about almost five years, which is a remarkable progress in addressing malnutrition nationally.

The Sustainable Development Goals (SDGs) and the 2030 Agenda for Sustainable Development have set ambitious targets to eradicate hunger and malnutrition worldwide. They are aspirational in nature and presents a challenging endeavour to collectively foster an equitable and inclusive future. SDG17 emphasizes the significance of global partnerships and multi-stakeholder collaborations to achieve these goals.

In response to this call, governments, civil society organizations, donors, private sector businesses, and international organizations have recognized their responsibility to combat all forms of malnutrition. The Tokyo Nutrition for Growth (N4G) Summit witnessed an unprecedented number of commitments in 2021, signalling a strong collective effort throughout the year. India released a pilot and thereafter made rice fortification compulsory over a similar timeline post 2020 (Ministry of Consumer Affairs, One Year of Announcement of Rice Fortification, 2022).

Food fortification has emerged as a crucial strategy in the fight against malnutrition induced by malnutrition, fostering public and private partnerships with positive impacts across various societal sectors. This document focuses on the significance of population-level food fortification programs in India, particularly highlighting rice fortification.

Despite significant strides, malnutrition remains a pressing issue in India. The collaboration of all stakeholders, including line ministries, experts, and the food industry, has been instrumental in tackling this challenge on a national scale. The document underscores the various benefits of rice fortification, such as improved nutritional status, reduced risk of chronic diseases, and enhanced economic productivity.

Extensive research supports the positive effects of rice fortification, including improved iron levels, increased haemoglobin concentrations, and reduced vitamin B12 deficiencies. Fortified rice holds immense potential in addressing prevalent micronutrient deficiencies in developing countries, leading to improved health outcomes, particularly for vulnerable groups. Nevertheless, further large-scale community-based studies are necessary to definitively establish its efficacy and impact.

[8] NITI Aayog published the Multidimensional Poverty Index (MPI) for India in 2021. This National MPI aims to deconstruct the Global MPI and develop a customized version for India, aligned with global standards. The objective is to design comprehensive Reform Action Plans to improve India's position in the Global MPI rankings. Additionally, the United Nations Development Programme (UNDP) and the Oxford Poverty & Human Development Initiative (OPHI) released the Global Multidimensional Poverty Index 2021.

India has made significant progress in its food fortification journey, starting with iodization of salt in the 1950s and expanding to fortify edible oil in the 1960s. Subsequent efforts included fortification of rice and wheat with essential nutrients through pilot projects, targeted initiatives, and large-scale implementations. The establishment of national food fortification standards in 2018 and the mandatory fortification of rice across the country in 2022 represent key milestones.

Food fortification is an effective and affordable approach to improve the nutritional well-being of the population, addressing issues like anaemia and micronutrient deficiencies. Challenges remain, and the government must continue investing in fortification programs to ensure equitable access to fortified foods for all segments of society. Key challenges include raising awareness, managing costs, improving access to fortified products, and fostering better coordination among stakeholders. Nevertheless, the momentum for food fortification in India is growing, and with continued commitment and effort, significant improvements in the population's nutritional status can be achieved through this strategic approach.

References

(2022). *2022 Global Nutrition Report: Stronger commitments for greater action.* Bristol, UK.

Administrative approval for Supply of Fortified Rice. (2022, April). Retrieved from Department of Food & Public Distribution: https://dfpd.gov.in/1sGbO2W68mUlunCgKmpnLF5WHm/pdf/Admn%20Approval%2018_4_22%20(1).pdf

Branca, D. F. (2017). *Malnutrition: It's about more than hunger.* Retrieved from WHO: https://www.who.int/news-room/commentaries/detail/malnutrition-it-s-about-more-than-hunger

(2020). *Combatting malnutrition by increasing uptake of fortified rice in India.* PATH. Retrieved from https://www.path.org/resources/combatting-malnutrition-increasing-uptake-fortified-rice-india/#:~:text=This%20fact%20sheet%20describes%20PATH%E2%80%99s%20work%20in%20collaboration,micronutrient%20malnutrition%2C%20especially%20among%20women%20and%20young%

Duggal, M., Sesikeran, B., Arlappa, N., Nair, S., Shekhar, V., & Sabharwal, V. (2022). Large-scale Staple Food Fortification as a Complementary Strategy to Address Vitamin and Mineral Vulnerabilities in India. *Indian Journal of Public Health*, 313-320. doi:10.4103/ijph.ijph_708_22

FFRC. (n.d.). *Rice Fortification.* Retrieved from FSSAI: https://fortification.fssai.gov.in/commodity?commodity=fortified-rice

(1997). *Food Fortification to End Micronutrient Malnutrition: State of the Art.* Ottawa, Canada: Micronutrient Initiative.

Guideline: fortification of rice with vitamins and minerals as a public health strategy. (2018). Geneva: World Health Organization.

Hussain, S. Z., Singh, B., & Rather, A. (2014). Efficacy of Micronutrient fortified Extruded Rice in Improving the Iron and Vitamin A status in Indian Schoolchildren. *International Journal of Agriculture and Food Science Technology, 5*, 227-238.

(2016). *Journey of Food Fortification: Fighting Malnutrition Improving Lives.* FSSAI. Retrieved from https://fortification.fssai.gov.in/assets/news/file/Journeyoffoodfortification_FightingMalnutritionImprovingLives.pdf#:~:text=This%20publication%20-%20%22Journey%20of%20Food%20Fortification%3AFighting%20Malnutrition%2C,food%20categories%20is%20achieved%20

Kapoor, A., & Green, M. (2022). *Social Progress Index: States and Districts of India.* EAC-PM. Retrieved from https://eacpm.gov.in/wp-content/uploads/2022/12/Social_Progress_Index_States_and_Districts_of_India.pdf

Kumar, R., & Shekhar, V. (2021). Rice Fortification is an Effective Way to Combat Anemia. Retrieved from NITI Aayog: https://www.niti.gov.in/rice-fortification-effective-way-combat-anemia

(2017). *Large Scale Food Fortification in India: The Journey So Far and Road Ahead.* FSSAI. Retrieved from https://fortification.fssai.gov.in/assets/media_gallery/file/Fortification_Report_New_REVISED.pdf

Ministry of Consumer Affairs, F. &. (2022). *One Year of Announcement of Rice Fortification.* Retrieved from PIB: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1850981

Ministry of Consumer Affairs, F. &. (2023). *269 districts in 27 states distributing Fortified Rice under Targeted Public Distribution System.* PIB Delhi. Retrieved from https://pib.gov.in/PressReleseDetail.aspx?PRID=1914231

Ministry of Consumer Affairs, F. &. (2023). *92.77 LMT of fortified rice lifted in Phase II under TPDS for Aspirational and High Burden Districts.* Delhi: PIB. Retrieved from https://pib.gov.in/PressReleseDetail.aspx?PRID=1907191

Mukherjee, S. (2011). *The Emperor of All Maladies.* Fourth Estate.

(2020). *National Family Health Survey (NFHS) 5.* Ministry of Health and Family Welfare, Government of India.

(2023). *National Multidimensional Poverty Index (MPI): A Progress Review 2023.* New Delhi: NITI Aayog. Retrieved from https://niti.gov.in/sites/default/files/2023-07/National-Multidimentional-Poverty-Index-2023-Final-17th-July.pdf

(1993). *National Nutrition Policy.* Departemnt of Women and Child Development. New Delhi: Ministry of Human Resiurce Development, Governemnt of India.

Osendarp, S. J., Martinez, H., Garrett, G. S., Neufeld, L. M., De-Regil, L. M., Vossenaar, M., & Darton-Hill, I. (2018). Large-Scale Food Fortification and Biofortification in Low-and Middle-Income Countries: A Review of Programs, Trends, Challenges, and Evidence Gaps. *Food and Nutrition Bulletin, 39(2)*, 315-331.

Peña-Rosas, J. P., Mithra, P., Unnikrishnan, B., De-Regil, N. K., Nair, N., Garcia-Casal, M. N., & Solon, J. A. (2019). Fortification of rice with vitamins and minerals for addressing micronutrient malnutrition. *Cochrane Database of Systematic Reviews.* doi:https://doi.org//10.1002/14651858.CD009902.pub2

Radhika, M. S., Nair, K. M., Kumar, R. H., Rao, M. V., Ravinder, P., Reddy, C. G., & Brahmam, G. N. (2014,). Micronized ferric pyrophosphate supplied through extruded rice kernels improves body iron stores in children: a double-blind, randomized, placebo-controlled midday meal feeding trial in Indian schoolchildren. *The American Journal of Clinical Nutrition, 94*, 1202–1210. Retrieved from https://doi.org/10.3945/ajcn.110.007179

Romana, D. L., Grieg, A., Thompson, A., & Arabi, M. (2021). Successful delivery of nutrition programs and the. *Current Opinion in Biotechnology.* Retrieved from https://pdf.sciencedirectassets.com/272028/1-s2.0-S0958166920X00061/1-s2.0-S0958166921000483/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEGsaCXVzLWVhc3QtMSJGMEQCIBGCWtPv1t6wTU9T006ODLJD3Pp3F%2FEMwFTvBAd9dnr%2BAiBLUnB7JkNbkllZx%2BW6Da0jNr6ATwiYr2A2t5y6gU

Thankachan, P., Rah, J. H., Thomas, T., Selvam, S., Amalrajan, V., Srinivasan, K., . . . Kurpad, A. V. (2012). Multiple Micronutrient-Fortified Rice Affects Physical Performance and Plasma Vitamin B-12 and Homocysteine Concentrations of Indian School Children. *The*

Journal of Nutrition, 142(5), 846-852. Retrieved from https://doi.org/10.3945/jn.111.149021

The Food Safety and Standards (Fortification of Foods) Regulations. (2018). *(F. No. 11/03/Reg/Fortification/2014).*

(2013). *The National Guidelines for Control of Iron Deficiency Anaemia.* Ministry of Health and Family Welfare, Government of India. Retrieved from https://www.nhm.gov.in/images/pdf/programmes/child-health/guidelines/Control-of-Iron-Deficiency-Anaemia.pdf

(2022). *The Proof Is In The Pilot: 9 Insights From India's Rice Fortification Pilot to-Scale Approach.* World Food Programme. Retrieved from https://docs.wfp.org/api/documents/WFP-0000141611/download/

Tulchinsky, T. H. (2010). Micronutrient Deficiency Conditions: Global Health Issues. *Public Health Review*, 243–255.

UNICEF. (2020). *Nutrition, for every child: UNICEF nutrition strategy 2020–2030*. UNICEF. Retrieved from https://www.unicef.org/reports/nutrition-strategy-2020-2030

Venkatesh, U., Sharma, A., Ananthan, V. A., Subbiah, P., Durga, R., & CSIR Summer Research training team. (2021). Micronutrient's deficiency in India: a systematic review and meta-analysis. *Journal of Nutritional Science, 10*. doi:10.1017/jns.2021.102