

Food Fortification and Leverages in Indian Food Stocks

Abstract:

The issue of micronutrient deficiencies like vitamins A, D and B12, iron, zinc, calcium, folate, etc, poses severe and even life-threatening health conditions. India is facing major challenges in terms of death due to severe anaemia, stunted physical and mental growth in children and incidental social and economic costs. Various international and national institutions have taken initiatives to mitigate these deficiencies through classical, industrial, food-to-food, home and biofortification. Indian authorities have successfully implemented a universal rice fortification programme through several government welfare schemes. Producers and manufacturers of staple foods like rice, wheat flour, oil, salt, milk, corn, and peas have fortified these essential items to meet the requirements of specific target groups and general populations. The present study, based mainly on secondary data, explores various fortification initiatives and their impact. The authors have observed the success of various initiatives taken by government and business houses. However, there is still a vast gap between goal and physical achievement at the ground level. The author advocates coordinated efforts at various levels to implement efficient and effective delivery and distribution management systems to mitigate severe public health issues and satisfy the requirements of SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth) and SDG 10 (Reduced Inequalities).

Keywords: Micro-nutrient deficiencies, Food Fortification, Global Hunger Index, Malnutrition, SDG-2

Introduction:

As per the World Food Programme (WFP), 'hidden hunger' affects more than two billion people globally due to micronutrient deficiencies (1). Micronutrient deficiencies occur when a diverse and nutrient-rich diet (including animal-source foods such as meat, eggs, fish, dairy, legumes, cereals, fruits and vegetables) is neither consistently available nor consumed in sufficient quantities. In 2021, WFP distributed 1478.081 thousand MT of fortified foods (\approx more than 3 billion rations), or enough for 17 million people to have their daily staple food consumption be in the form of fortified staples for six months (1), occupying 107th position among 121 nations in the Global Hunger Index 2023 with a score of 29.1 (20.00 – 34.90) (27). Factors like deplorable socio-economic conditions, gender disparity, food habits, involuntary unemployment, lack of medical facilities, migration, bureaucracy, blood loss during menstruation, poor hygiene and sanitary practices, and lack of educational and general awareness contribute to malnutrition. (overnutrition, undernutrition, and micronutrient deficiencies). As per the 2024 Global Hunger Index (GHI), India ranks 105th out of 127 countries with sufficient data to calculate the 2024 GHI score of India, which stands at 27.3, which indicates that the rise in hunger is alarming and challenging (2), (27), (28).

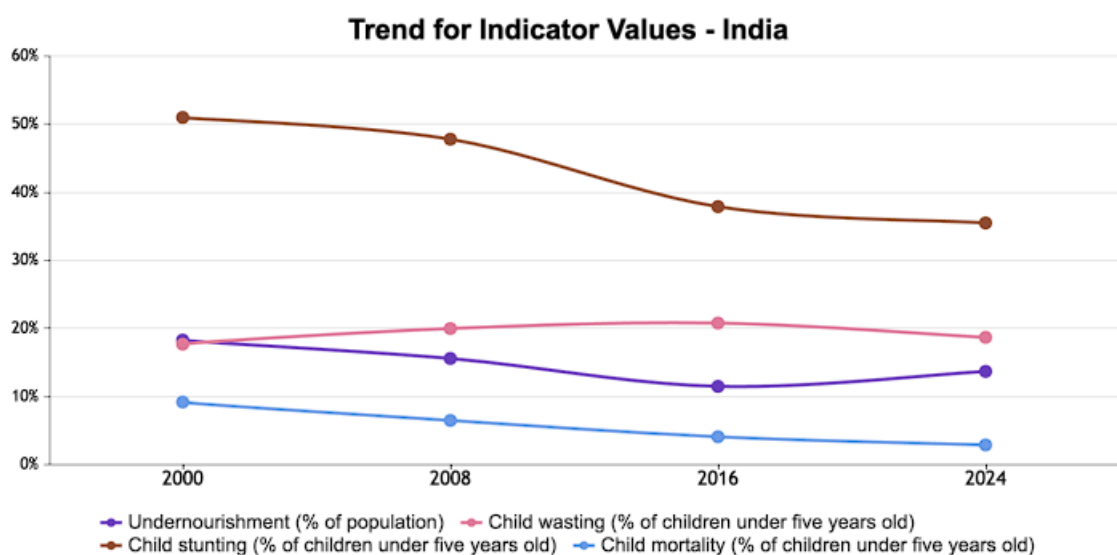
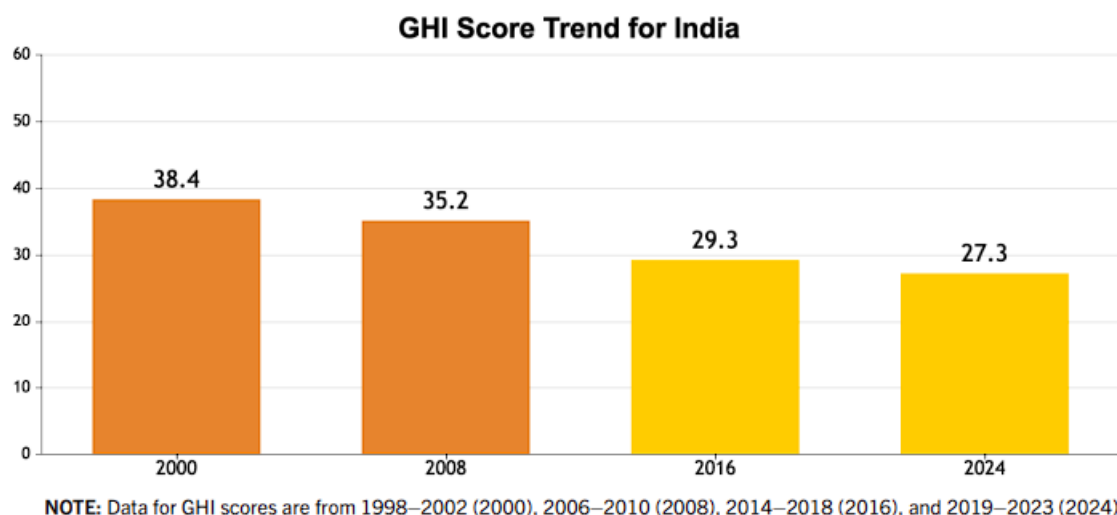


Fig 1: Global Hunger Index (GHI), 2024GHI scores are from 1998–2002 (2000), 2006–2010 (2008), 2014–2018 (2016), and 2019–2023 (2024); the trend for the indicator values (source: <https://www.globalhungerindex.org/pdf/en/2024/India.pdf>)

Niti Ayog published an article on rice fortification dated 28.10.21 and observed satisfaction with the progress of the rice fortification programme in reducing stunting and anaemia (46). The paper also refers to the WHO, which has declared anaemia a severe public health issue among women and children, demanding immediate attention. The paper relates to FAO attributing cost-intensive health diets as a global constraint to achieving the nutrition-related Sustainable Development Goals (47). According to the National Family Health Survey (NFHS-5) conducted between 2019 and 2021, anaemia remains a widespread issue in India, affecting children, women, and men across various age groups and income levels. Since health is under the jurisdiction of the State, the press release outlines the policy initiative towards centre-state cooperation in eliminating said alarming situation (ANAEMIA MUKT BHARAT, Posted On: 04 FEB 2022 5:30 PM by PIB Delhi). Global Alliance for Improved Nutrition (GAIN) impacts large-scale food fortification (LSFF) at regional, country, and international levels through relevant legislative, regulatory, governance and institutional measures. Their effort encompasses developing compliance mechanisms, quality assurance, supply chain management, value chain analysis and sustainable marketing efforts (29). Food

safety regulator FSSAI prescribe blending of rice with three micronutrients, i.e. Iron, Folic Acid and Vitamin B12. (Hindu, Business Line dated 10.10.24). The food fortification programme commenced in 2022, and the Union Cabinet has approved the continuation of fortified rice distribution with an estimated cost of over ₹17,000 crore until December 2028 under all government welfare schemes like POSHA Abhiyaan, Pradhan Mantri Matru Vandana Yojana (PMMVY), Integrated Child Development Services (ICDS), Pradhan Mantri Poshan Shakti Nirman (PM POSHAN) and Pradhan Mantri Garib Kalyan Anna Yojana (PMJKAY). (PIB press release dated 11th October 2024)

Literature Review

Food fortification adds micronutrients like vitamins and minerals to food, improving its nutritional superiority. Food manufacturers or governments can enhance nutritional quality, prevent deficiencies, restore lost nutrients, and be cost-effective. Such fortified foods include Asbah - Silver Rice, Ashirwad Chakki Atta, TATA Salt, Krushna milk, and Zinc in junk foods (3), (4), (5), (22). In some countries, vitamin A supplementation, iodised salt addition, Vitamin A and D addition in oil, Iron-rich foods, etc., can help the community manage acute malnutrition through nutrient supplementation (18), (19), (21). The strategy of fortification of dietary consumption with nutrient-rich food-based fortifiers. It is warranted that countries with malnutrition among children, women, and financially backwards people need grading of recommendations, development, and research evidence in economically backward countries (6), (9), (10). The most efficient and cost-effective methodology to maintain public health is going for food fortification. Federal fortification policies and protocols can diminish health maladies and food insecurities among citizens in a country by altering the taste and behaviour of the people's diet (11), (12), (13), (14). According to the National Family Health Survey (NFHS-5) conducted between 2019 and 2021, anaemia remains a widespread issue in India, affecting children, women, and men across various age groups and income levels. World Health Organisation (WHO) describes food fortification as deliberately increasing the content of one or more micronutrients (i.e. vitamins and minerals) in food or condiments to improve the nutritional quality of the food supply and provide a public health benefit with minimal health risk (24). According to the National Cancer Institute, food fortification is food with extra nutrients that are generally not there. Examples 'milk with vitamin D and salt with Iodine added.' As per FASSI, food fortification (with the +F logo) is a scientifically proven, cost-effective, scalable, and sustainable global intervention that addresses the issue of micronutrient deficiencies. FASSI has notified the Food Safety and Standards (Fortification of Foods) Regulations 2016 in the Gazette of India. The process has been operationalised by fortifying rice with iron vitamin B12 and folic acid, double-fortified salt with iodine and iron milk, and edible oil with vitamins A and D. The celebrated UNO agency World Food Programme (WFP) is globally recognised for its groundwork among poor and backward countries to fight hunger and malnutrition also supply fortified rice.

So, food fortification has become a nationally debatable issue in the Indian context, and the country's people must thoroughly analyse and appraise it.

Objectives of the Study:

- i. Factors contributing to the programme of implementation of food fortification by respective authorities.**

- ii. To find out the implications of food fortification on the health conditions of the general population

Methodology

Data Collection and Statistical Tools Applied for Interpretation of Data

The data is mainly collected from secondary sources, such as websites and publications of reputed and established national and international agencies engaged with food fortification programmes, namely WHO, UNICEF, WFP, GAIN, FASSI, etc. The authors have referred to articles published in research-based journals to gain insight into their respective studies' problem areas and conclusions. The authors have gathered vital input on the subject by informally interacting with experts in this field. The authors employed various statistical tools, such as EXCEL and SPSS, to interpret data collected from secondary sources (24).

General Methods of Fortification and Impact on General Population

As per WHO and FAO, fortification can be described under three broad categories depending upon the 'target population.' 'Mass fortification' is the first category for the wider public and is generally mandatory. The second category, 'target fortification', is meant for well-defined population subgroups with voluntary or compulsory choices. The third, 'market-driven fortification', adheres to regulatory requirements but is transacted in marketplaces Figure 2. (25).

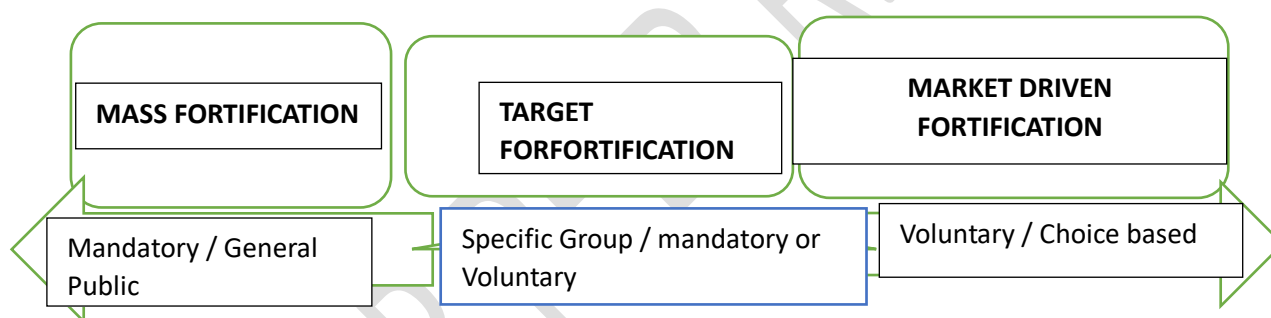


Fig 2: Methodology for grouping of Food fortification in India

Type of Fortification:

Table 1: Types of food fortification in India (Classical, industrial, bio, food to food, etc.)

Fortification Type	Descriptions
Classical Food Fortification	Increase micronutrients in essential and staple foods like rice, rice flour, wheat flour, corn, edible oil, fats, milk, salt and sugar by adding synthetic vitamins and minerals (26).
Industrial / Large Scale Fortification	Micronutrients are added during mass manufacturing of rice, flour, cooking oil sauce, condiments, etc, like potassium iodide or iodate to edible salt. Fortified rice kernels (FRK) are mixed with regular and non-fortified rice in a ratio of 1:100. Rice flour combined with the required micronutrients produces the end product of FRK. With the sheen, transparency, flavour and consistency of regular rice, it is mixed with rice. Industrial fortification of rice is prevalent in most government schemes and mid-day meals. Field studies have shown reduced cases of stunting and underweight among the sample population. (30)

Biofortification	Process of improving the nutritional quality of food crops and reducing antinutritional factors through conventional breeding, agronomic practices, genetic engineering or genome editing. The examples are partially iron-biofortified rice in the Philippines targeting reproductive-age women, iron-biofortified pearl millet improving iron deficiency in school children of India and iron-biofortified beans for women in Rwanda (31) (32).
Food-to-Food Fortification	It is an emerging food-based strategy with available local resources like staple fruits and vegetables the local population consumes to target micronutrient deficiencies. (33)
Point-of-use/home fortification	One of the easiest ways of adding micronutrients is by sprinkling iron or powdered nutrients on tablets while cooking or eating food. (Link-10). Interventions through micronutrient powder (MNP), such as iron, zinc, and vitamin A at home (point-of-use) fortification of foods, were found to be reliable, cost-effective, convenient, and simple methods. Field trials in low-income countries in Asia, Africa and the Caribbean through home-fortification intervention reduced anaemia and iron deficiency (34)(35)

World Health Organisation (WHO) describes food fortification as deliberately increasing the content of one or more micronutrients (i.e. vitamins and minerals) in food or condiments to improve the nutritional quality of the food supply and provide a public health benefit with minimal health risk., Mishra et al (36) According to the National Cancer Institute, food fortification is food with extra nutrients that are generally not there. Examples ‘milk with vitamin D and salt with Iodine added.’ As per FASSI, food fortification (with the +F logo) is a scientifically proven, cost-effective, scalable, and sustainable global intervention that addresses the issue of micronutrient deficiencies (37). FASSI has notified the Food Safety and Standards (Fortification of Foods) Regulations 2016 in the Gazette of India. The process has been operationalised by fortifying rice with iron vitamin B12 and folic acid, double-fortified salt with iodine and iron milk and edible oil with vitamins A and D. Extrusion Method is the most common method used in India. Rice flour is mixed with premix (a blend of vitamins and minerals) and then passed through an extruder to form fortified rice kernels (FRKs). These kernels are similar in size, shape, and appearance to regular rice grains. Blending: The fortified kernels (FRKs) are then combined with regular rice at a ratio (usually 1:100 or 1:200) to create fortified rice. This mixture ensures that the fortified rice has a consistent distribution of nutrients. The food fortification programme commenced in 2022, and the Union Cabinet has approved the continuation of fortified rice distribution with an estimated cost of over ₹17,000 crore until December 2028 Ganachari et al. (17). Food safety regulator FSSAI prescribe blending rice with three micronutrients, i.e. Iron, Folic Acid and Vitamin B12. The benefits derived from this fortification programme aim at preventing anaemia widespread among children, women, and men across all age groups, resulting in control over the loss of 1% GDP. The anaemia contributes towards an estimated Rs 70,000 cr in terms of death, illness, and loss of productivity. (Hindu, Business Line). As per the Press Information Bureau (PIB) Report dated 11th October 2024, custom-milled rice has been replaced with fortified rice in every scheme of the Government, and 100% coverage of distribution of fortified rice has been achieved. With an estimated domestic consumption of about 94-95 million metric tonnes, wheat is a staple food in wheat-growing regions spanning

north, central, and western India. Due to increased disposable income, urbanisation, changes in preferences and tastes, and adding outside food to Indian palates, products made from wheat flour like chapati, naan, and roomali roti have gained acceptance and popularity. Wheat consumption is registering steady growth on a y-to-y basis, and wheat occupies a prominent place in MSP structure and PDS. Fortification of wheat flour is a safe, cost-effective, and convenient method for improving public health, especially in fighting anaemia and improving blood formation. During the industrial milling process, there are chances of nutrient losses, and fortification is an effective way of replenishing these lost nutrients. Indian food conglomerates like Adani, Patanjali, HUL, ITC, and Cargill enjoy a substantial market share in wheat flour, with reputed and well-established brands fortifying their wheat flour by adding vitamin B-12, Folic acid, and Iron (38). Generally, the salts are fortified with nutrients like iodine, iron and folic acid by reputed salt brands like Tata, Aashirvad, Catch, Saffola, and Puro. The disease and conditions like goitre, hypothyroidism, growth and developmental abnormalities and learning disabilities occur due to iodine deficiency. Anaemia caused by iron deficiency leads to various ailments, and most of the population suffers from these wide-ranging symptoms. It has been researched and clinically proven that fortified iodised salt has reduced the incidence of these diseases (39). Double Fortified Salt (DFS), a table salt with added iodine and iron, has successfully overcome widespread iodine and iron deficiency among women and children in urban and backward areas. Double Fortified Salt (DFS) formulation developed by the National Institute of Nutrition (NIN), India, intends to supplement 100% of the daily dietary iodine requirement and ~30 to 60% of the daily nutritional iron requirement. The technology has been transferred to salt manufacturers, enabling the country to sustainably mitigate iron and iodine deficiencies. The Ministry of Health and Family Welfare endorsed the addition of iron in double-fortified salt at 0.8-1.1 mg/g of salt in 2009 (40). Maize is grown all around the globe, having diverse climatic conditions, and the produce has varied food and industrial usage. In many areas, especially tribal, hilly and arid regions, corn or maize is a staple food, especially among deprived, undernourished and malnourished populations. The maize can be consumed as flatbread, porridge, vegetables, cornflakes, snack items etc. WHO guidelines recommend fortification of corn or maize with micronutrients like iron, folic acid, zinc, vitamin A and vitamin B-complex (41).

Results

The presence of active components in spices and condiments like phthalides, polyacetylenes, phenolic acids, flavonoids, coumarins, triterpenoids, sterols and monoterpenes have multiple mental, physical and emotional benefits. They possess antibiotic, antioxidant, antiviral, anticoagulant, anti-inflammatory, and anticarcinogenic properties. The authors advocate that the main nutritional problems are micronutrient deficiencies, and fighting these issues through the fortification of staple foods has been the focus of policymakers and governments worldwide. But in some instances, condiments and seasonings that are widely used, like fish and soya sauces, curry powder, and mayonnaise, can provide helpful and practical alternatives to fight micronutrient deficiencies. Sauces, spices and condiments: definitions, potential benefits, consumption patterns and global market by Maria N Gracia-Casal, Jp Pena-Rosas and Heber-Gomez – Malave', *Annals of the New York Academy of Sciences*, 2016. FASSI recommends the addition of fat-soluble vitamins like vitamins A and D to fight micronutrient malnutrition, considering the consumption of edible oil about 20-30 g / person/day, a considerably high figure as per 2011 NSSO data. The fortification of edible oil

would address the issue of vitamin deficiency conditions like morbidity, mortality, productivity, and social and economic growth (42). During the fat removal process from milk, many essentials and nutritional elements like protein, calcium, vitamins A and D are depleted. (43) Hence, many countries worldwide, including the USA, have made it mandatory to add back the vitamins removed in the process. Milk is fortified by adding zinc, iron, and folic acid, including vitamins A and D. As per the TATA Trust study, a glass of milk provides (150 ML) nearly 20% of the daily vitamin A requirement and 15% of vitamin D (approx.) (44). In contrast, AMUL, the leading milk brand, favours natural fortification and avoids artificial fortifications. (45).

Table 2: The food vehicle and the components of Nutrients added

Items	Component of Nutrients added
Iodised Salt and Double Fortified Salt	Iodine, Iron content (as Fe)
Fortified Oil	Vitamin A, Vitamin D
Fortified Milk	Vitamin A, Vitamin D
Fortified Atta	Iron, Folic Acid, Vitamin B12, Zinc Sulphate and Vitamin A , Vitamin B1, Vitamin B2, Vitamin B3 , Vitamin B6
Fortified Maida	Iron, Folic Acid, Vitamin B12, Zinc, Vitamin A, Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B6
Fortified Raw Rice	Iron, Folic Acid, Vitamin B12, Zinc, Vitamin A, Vitamin B1, Vitamin B2, Vitamin B3, Vitamin B6
Fortified Cereal Products	Iron, Folic Acid, Vitamin B12, Zinc, Vitamin A, Vitamin B1, Vitamin B3, Vitamin B6
Fortified Bakery Wares	Iron, Folic Acid, Vitamin B12, Zinc, Vitamin A, Vitamin B1, Vitamin B2 , Vitamin B3 , Vitamin B6
Fortified Fruit Juices	Vitamin C

(Source: Food Safety and Standards Authority of India)

Discussion

Based on the study mainly conducted through secondary sources, it has been observed that the result of the field study indicates that food fortifications make a positive and long-term impact on both the general and targeted population. It's accepted that most of the global population, especially in developing and developed countries, face serious health issues. Micronutrient deficiencies like vitamins, iron, zinc, iodine, and folic acid pose health problems for newborns, pregnant women, children, and grownups. These minor deficiencies, which can be easily mitigated through industrial, classical and point-to-use (home) fortifications, remain challenging at the distribution and field level. The reason may be attributed to belief and value systems, lack of knowledge, access to medical care, lack of coordination among implementing agencies, faulty implementations by various agencies, and inadequate supply chain and value chain analysis at multiple stages (17). The consequent health problem implies a heavy burden on public finance apart from stress building on existing fragile health infrastructure and delivery system at the grassroots level. As observed during the study, welfare states like India have achieved notable progress, especially in delivering essential staple foods like rice, salt, milk, peas, edible oil and wheat flour. Many experts point out that more than merely allocating funds for the food fortification programme is needed to achieve the target. The delivery and implementation network at panchayat,

block, district, state, and centre levels should be in tandem and in mission mode to achieve the goal of wiping out 'micronutrient deficiency'.

Conclusion

The anaemia contributes towards an estimated Rs 70,000 cr in terms of death, illness, and loss of productivity. The benefits derived from the fortification programme aim at preventing anaemia widespread among children, women, and men across all age groups, resulting in control over the loss of 1% of GDP. (Hindu, Business Line dated 10.10.24). The strategic objective of India achieving developed economy status would remain a distant dream unless this avoidable issue of micronutrient deficiencies is resolved in mission mode. All the stakeholders, like legislative wings of state and centre, policymakers, national and international institutions, NGOs, regulating agencies, implementing agencies, and primary health workers, need to have a synergetic relationship both at the ground and policy levels to achieve this long-term sustainable objective. The mission and vision of our political and social leadership, including our business leaders, need to be aligned strategically on this focused area. The profit motive may drive the market economy, but a business's ethical and social responsibility calls for achieving food and nutritional security for the nation. Perhaps the most vital link in this entire value chain is women's empowerment and the subtle and significant role of mothers and women in the household. The government has already laid down an efficient and effective launchpad for food fortification through various welfare programmes. But the result remains at ground level to achieve the overall objective of minimising the adverse impact of micronutrient deficiencies through mitigating measures like various food fortification programmes.

Ethics Approval: Not applicable.

Data availability

Abbreviations: All abbreviations have expansions during their first use within the text.

References:

1. WFP Myanmar. (n.d.). Rice fortification. In WFP Myanmar. <https://cdn.wfp.org/wfp.org/publications/Rice%20Fortification%20Factsheet.pdf>
2. Victoria Bell, Ana Rita Rodrigues, Jorge Ferrão, Theodoros Varzakas, Tito H. Fernandes, The Policy of Compulsory Large-Scale Food Fortification in Sub-Saharan Africa, *Foods*, 10.3390/foods13152438, 13, 15, (2438), (2024).
3. Tsang BL, Deshpande S, Varghese M, Jain S, de Romana DL, Chadha M. Introducing double fortified salt in social safety net programs in Madhya Pradesh and Gujarat in India: Success factors, challenges and lessons learned. *Matern Child Nutr.* 2024 Jun 5:e13646. doi: 10.1111/mcn.13646.
4. Neufeld LM, Aaron GJ, Garrett GS, Baker SK, Dary O, Van Ameringen M. Food fortification for impact: a data-driven approach. *Bull World Health Organ.* 2016 Aug 1;94(8):631-2. doi: 10.2471/BLT.15.164756. Epub 2016 Jul 5.
5. Kaur N, Agarwal A, Sabharwal M. Food fortification strategies to deliver nutrients for managing iron deficiency anaemia. *Curr Res Food Sci.* 2022 Oct 23;5:2094-2107. doi: 10.1016/j.crfs.2022.10.020.

6. Mishra D. P., Mishra S. P., Mishra N. and Sahoo M., Nov 2018, Productivity, Production, and Export of Food Grains: Odisha's Context to Indian Strategies, *Journal of Advanced Research*, Vol- 6(11): pp- 767-779, DOI: 10.21474/IJAR01/8057
7. NITI Aayog (Led by Shri Alok Kumar, Dr Supreet Kaur, Anamika Singh), along with a team from the Int. Food Policy Research Institute (IFPRI) led by Dr Punima Menon. *Poshan Abhijan, Accelerating Progress Nutrition in India (Third Progress Report)*, 2020; p 1-79
8. PIB; Ministry of Consumer Affairs, Food and Public Distribution. *Nutritious Boost: Free Fortified Rice for a Healthier India*. Press Information Bureau, Posted On: 11 OCT 2024 2:08PM
9. Friesen VM, Mbuya MNN, Wieringa FT, Nelson CN, Ojo M, Neufeld LM. Decisions to Start, Strengthen, and Sustain Food Fortification Programs: An Application of the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Evidence to Decision (EtD) Framework in Nigeria. *Curr Dev Nutr*. 2022 Jan 31;6(3):nzac010. doi: 10.1093/cdn/nzac010.
10. Endevelt R, Tulchinsky TH, Stahl Z, Mor Z, Davidovitch N, Levine H, Troen AM. Challenges and obstacles implementing evidence-based food fortification policy in a high-income country. *Front Public Health*. 2023 Mar 16;11:1052314. doi: 10.3389/fpubh.2023.1052314.
11. Bourassa MW, Atkin R, Gorstein J, Osendarp S. Aligning the Epidemiology of Malnutrition with Food Fortification: Grasp Versus Reach. *Nutrients*. 2023 Apr 22;15(9):2021. doi: 10.3390/nu15092021.
12. Global Fortification Data Exchange (GFDX). (2022). Available online at: <https://fortificationdata.org/chart-year-when-food-fortification-mandated/>; <https://fortificationdata.org/full-gfdx-datasets/>
13. Rohner F, Wirth JP, Zeng W, Petry N, Donkor WES, Neufeld LM, Mkambula P, Groll S, Mbuya MN, Friesen VM. Global Coverage of Mandatory Large-Scale Food Fortification Programs: A Systematic Review and Meta-Analysis. *Adv Nutr*. 2023 Sep;14(5):1197-1210. doi: 10.1016/j.advnut.2023.07.004.
14. Wessells KR, Manger MS, Tsang BL, Brown KH, McDonald CM. Mandatory large-scale food fortification programmes can reduce the estimated prevalence of inadequate zinc intake by up to 50% globally. *Nat Food*. 2024 Jul;5(7):625-637. doi: 10.1038/s43016-024-00997-w.
15. Mishra D. P., Mishra S. P., Organic Farming: Paradigm Shift during Pandemic to "Food Safety" Complying "Food Security" in India; *Annual Research and Review in Biology* 35(10):63-74, (Oct- 2020); DOI: 10.9734/ARRB/2020/XXXXX
16. Ganachari, A., Nidoni U., Hiregoudar S., Ramappa KT., Naik,2 S. Vanishree,3 and P. F. Mathad2 Development of rice analogues fortified with iron, folic acid and Vitamin A , *J Food Sci Technol*. 2022 Sep; 59(9): 3474–3481. Published online 2022 Jan 11. doi: 10.1007/s13197-021-05337-5)
17. Ajith Athrady. (2024, October 9). Cabinet okays fortified rice supply under welfare schemes till Dec 2028 at Rs 17,000 cr cost. *Deccan Herald*. <https://www.deccanherald.com/india/cabinet-okays-fortified-rice-supply-under-welfare-schemes-till-dec-2028-at-rs-17000-cr-cost-3225748> 17:21 IST
18. Mishra D. P., Mishra S. P., Mishra N., 2018, Vol 5(3) *The Enhanced Inland Food Chain and Export Disparities of Small Cardamoms in India: A Critical Review*, *International journal of research and analytical review*, PP- 448-463

19. Olson R, Gavin-Smith B, Ferraboschi C, Kraemer K. Food Fortification: The Advantages, Disadvantages and Lessons from Sight and Life Programs. *Nutrients*. 2021 Mar 29;13(4):1118. doi: 10.3390/nu13041118.
20. WHO, Mobilizing Ambitious and Impactful Commitments for Mainstreaming Nutrition in Health Systems: Nutrition in universal health coverage, Global Nutrition Summit. Geneva: World Health Organization; (2020).
21. Nishijima C, Sato Y, Chiba T. Nutrient Intake from Voluntary Fortified Foods and Dietary Supplements in Japanese Consumers: A Cross-Sectional Online Survey. *Nutrients*. 2023 Jul 10;15(14):3093. doi: 10.3390/nu15143093.
22. Das JK, Salam RA, Mahmood SB, Moin A, Kumar R, Mukhtar K, Lassi ZS, Bhutta ZA. Food fortification with multiple micronutrients impacts health outcomes in the general population. *Cochrane Database Syst Rev*. 2019 Dec 18;12(12):CD011400. doi: 10.1002/14651858.CD011400.pub2.
23. Wessells KR, Manger MS, Tsang BL, Brown KH, McDonald CM. Mandatory large-scale food fortification programs can reduce the estimated prevalence of inadequate zinc intake by up to 50% globally. *Nat Food*. 2024 Jul;5(7):625-637. doi: 10.1038/s43016-024-00997-w.
24. Nayak, S. K., Beura, M., Siddique, M., and Mishra, S. P. (2021). Analysis of Indian Food Based on Machine Learning Classification Models. *Journal of Scientific Research and Reports*, 27(7), 1-7. <https://doi.org/10.9734/jsrr/2021/v27i730407>
25. Thakur S., Singh A., Insa B., Sharma S. 'Food fortification in India as malnutrition concern: a global approach' *Journal Sustainable Food Techno*, 2023, 1, 681-695
26. Chadare, F. J., Idohou, R., Nago, E., Affonfere, M., Agossadou, J., Fassinou, T. K., Kénou, C., Honfo, S., Azokpota, P., Linnemann, A. R., & Hounhouigan, D. J. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food Science & Nutrition*, 7(9), 2781–2795. <https://doi.org/10.1002/fsn3.1133>
27. Index, G. H. (2024, October 22). India. Global Hunger Index (GHI) - Peer-reviewed Annual Publication Designed to Comprehensively Measure and Track Hunger at the Global, Regional, and Country Levels. <https://www.globalhungerindex.org/india.html>
28. BBC News. (2021, February 18). Malnutrition is rising across India - why? <https://www.bbc.com/news/world-asia-india-56080313>
29. What is Large Scale Food Fortification (LSFF)? (2022, August 29). GAIN. <https://www.gainhealth.org/media/news/what-large-scale-food-fortification-lsff>
30. Ahuja, A. (2020). POSHAN Maah 2020: Three different ways of food fortification explained. In S. Bhaskar (Ed.), *National Nutrition Month* [Article]. https://www.fssai.gov.in/upload/media/FSSAI_News_Fortification_Banega_18_09_2020.pdf
31. Biofortification. (2023, March 15). International Rice Research Institute. <https://www.irri.org/biofortification>
32. Elise F. Talsma (June 2017). Biological, behavioural and contextual rationale. (n.d.-a). Retrieved from <https://www.who.int/tools/elena/bbc/biofortification>
33. Kruger, J., Taylor, J. R. N., Ferruzzi, M. G., & Debelo, H. (2020). What is food-to-food fortification? A working definition and framework for evaluation of efficiency and implementation of best practices. *Comprehensive Reviews in Food Science and Food Safety*, 19(6), 3618–3658. <https://doi.org/10.1111/1541-4337.12624>

34. UNICEF, World Health Organization, & Home Fortification Technical Advisory Group. (2023). Home Fortification with Multiple Micronutrient Powders for the Prevention of Iron Deficiency Anaemia in Early Childhood. Brief Guidance Note. <https://www.unicef.org/media/145741/file/Home>.
35. Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age | GAIN. (n.d.). Retrieved from <https://www.gainhealth.org/resources/reports-and-publications/home-fortification-foods-multiple-micronutrient-powders-health>
36. Food fortification. WHO. [www.who.int. https://www.who.int/health-topics/food-fortification](https://www.who.int/health-topics/food-fortification)
37. FSSAI. (n.d.). [Fssai.gov.in. https://fssai.gov.in/cms/fortified-food.php](https://fssai.gov.in/cms/fortified-food.php)
38. Schroeder, E. (2017, April 10). Indian companies to fortify wheat flour. World-Grain.com; World Grain. <https://www.world-grain.com/articles/7976-indian-companies-to-fortify-wheat-flour>
39. S., B. (2025). Fortification of salt with iron and iodine to control anaemia and goitre: Development of a new formula with good stability and bioavailability of iron and iodine. Unu.edu; United Nations University. <https://archive.unu.edu/unupress/food/8F151e/8F151E06.htm>
40. Commodity View : Fortification. (2015). [Fssai.gov.in. https://fortification.fssai.gov.in/commodity?commodity=double-fortified-salt](https://fortification.fssai.gov.in/commodity?commodity=double-fortified-salt)
41. Fortification of maize flour and corn meal. (n.d.). [Www.who.int. https://www.who.int/tools/elena/interventions/maize-fortification](https://www.who.int/tools/elena/interventions/maize-fortification)
42. Edible Oil. (n.d.). [Fortification.fssai.gov.in. https://fortification.fssai.gov.in/commodity?commodity=fortified-oil](https://fortification.fssai.gov.in/commodity?commodity=fortified-oil)
43. Food Fortification: Technology and Quality Control. (1997, November). [Fao.org; Food and Agriculture Organization of the United Nations Rome. https://www.fao.org/4/w2840e/w2840e03.htm#food%20fortification%20technology](https://www.fao.org/4/w2840e/w2840e03.htm#food%20fortification%20technology)
44. The scoop on fortified milk. (2020, March 13). [Tata Trusts. https://www.tatatrusters.org/our-stories/article/the-scoop-on-fortified-milk](https://www.tatatrusters.org/our-stories/article/the-scoop-on-fortified-milk)
45. Awana, A. (2019, August 30). Not opposed to fortified milk but prefer natural one: Sodhi. Indian Cooperative | News Exclusively from the Cooperative Sector. <https://www.indiancooperative.com/co-op-news-snippets/not-opposed-to-fortified-milk-but-prefer-natural-one-sodhi/>
46. Rice fortification is an effective way to combat anemia | NITI Aayog. (2021, October 28). [Www.niti.gov.in. https://www.niti.gov.in/rice-fortification-effective-way-combat-anemia](https://www.niti.gov.in/rice-fortification-effective-way-combat-anemia)
47. SDG INDIA Index & Dashboard 2020-21 Partnerships in the Decade of Action. (2021). https://sdgindiaindex.niti.gov.in/assets/Files/SDG3.0_Final_04.03.2021_Web_Spreads.pdf

1. <https://cdn.wfp.org/wfp.org/publications/Rice%20Fortification%20Factsheet>
2. <https://docs.wfp.org/api/documents/WFP-0000139908/download/?>
3. <https://cdn.wfp.org/wfp.org/publications/Rice%20Fortification%20Factsheet.pdfIndia>
4. <https://www.globalhungerindex.org/india.html>
5. <https://www.bbc.com/news/world-asia-india-56080313>



6. <https://onlinelibrary.wiley.com/doi/full/10.1002/fsn3.1133>
7. <https://www.gainhealth.org/media/news/what-large-scale-food-fortification-lsff>
8. <https://onlinelibrary.wiley.com/doi/full/10.1002/fsn3.1133>
9. https://fssai.gov.in/upload/media/FSSAI_News_FortificationBanega_18_09_2020.pdf
10. <https://www.irri.org/biofortification>
11. <https://www.who.int/tools/elena/bbc/biofortification#>
12. <https://ift.onlinelibrary.wiley.com/doi/10.1111/1541-4337.12624>
13. <https://www.unicef.org/media/145741/file/Home>.
14. <https://www.gainhealth.org/resources/reports-and-publications/home-fortification-foods-multiple-micronutrient-powders-health>
15. https://www.who.int/health-topics/food-fortification#tab=tab_1.
16. <https://fssai.gov.in/cms/fortified-food.php>
17. <https://www.world-grain.com/articles/7976-indian-companies-to-fortify-wheat-flour>
18. <https://archive.unu.edu/unupress/food/8F151e/8F151E06.htm>
19. <https://fortification.fssai.gov.in/commodity?commodity=double-fortified-salt>
20. <https://www.who.int/tools/elena/interventions/maize-fortification#:~>
21. <https://fortification.fssai.gov.in/commodity?commodity=fortified-oil>
22. <https://www.fao.org/4/w2840e/w2840e0b.htm>
23. <https://www.tatatrusts.org/our-stories/article/the-scoop-on-fortified-milk>
24. <https://www.indiancooperative.com/co-op-news-snippets/not-opposed-to-fortified-milk-but-prefer-natural-one-sodhi/>
25. <https://www.deccanherald.com/india/cabinet-okays-fortified-rice-supply-under-welfare-schemes-till-dec-2028-at-rs-17000-cr-cost-3225748>