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“Nutrition Reinvented: A Comprehensive Review Of Food Fortification Strategies And Implementation”

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Abstract

Micro-nutrient deficiencies or “Hidden hunger”, affects over 2 billion people worldwide and causes anemia, stunted growth, weak immunity, and cognitive delays. Food fortification has emerged as a key public health strategy to address these deficiencies. This review compiles information on fortification strategies, techniques, implementation methods and challenges based on historical development, global initiatives, and India's national programs. Addition of micro-nutrients to everyday foods has proven effective in reducing nutritional deficiencies. India's +F program, launched by FSSAI in 2016, is among the largest, standardizing fortification for rice, wheat flour, oils, double-fortified salt, and milk. Methods range from dry mixing to pelleting, though challenges like tech limits, regulations, acceptance, and equity persist. Food fortification offers proven health, economic, and social gains. Its Success depends on strong political will, strong regulations, partnerships, innovation, and ties to wider nutrition plans.

Keywords: Food fortification, micro-nutrient deficiencies, hidden hunger, public health, nutrition policy, FSSAI, +F program

Introduction

Around 2 billion people suffer from "hidden hunger" caused by micro nutrient deficiencies¹, India shares a disproportionate number of micro-nutrient deficiency-related health risks (e.g., neural tube defects (NTDs), blindness, and anemia ². The WHO recognizes micro nutrient deficiencies as a major barrier to achieving global health, nutrition, and development goals. Nutrient enrichment of foods can help prevent nutritional inadequacies in population at risk and correct a proven deficiency in vulnerable groups. Fortification of commonly consumed foods with essential nutrients improves dietary intake in an effective and sustainable

manner. This review article discusses about food fortification, its global impact, history, strategies, challenges, and future prospects, with special emphasis on India's initiatives.

Methodology: This systematic review employed content analysis of existing fortification program documentation and policy framework, with information from published literature, policy reports and secondary sources.

Discussion:

Historical Development and Evolution:

Global Historical Context:

Early Beginnings: The concept of adding substances to a food/beverage to affect a biological function was first recorded in 400 B.C. by the Persian physician Melanpus, suggested adding iron filings to wine to increase soldier's potency. However, modern food fortification began during the early 20th century:³

Table No. 1

1923	Switzerland became the first country to fortify salt with iodine to eliminate goiter.
1924	The United States followed Switzerland to fortify salt with iodine.
1930-1940	Industrial-scale synthesis of vitamins and minerals made large-scale food fortification technically and economically feasible.
1943	Mandatory fortification of wheat flour with bread in the United States.
1990-2000	Fortification initiatives expanded globally, including salt iodization, wheat flour fortification, and addition of folic acid to prevent neural tube defects.

India's Fortification Journey: India's approach to food fortification has evolved gradually over several decades.

Table No. 2

1950	Initial fortification efforts began with vegetable oil fortification and salt iodization
2000	Government introduced fortification of other commodities such as rice and wheat 60-year gap between global evidence.
2016	A significant milestone was achieved when the Food Safety and Standards Authority of India (FSSAI) established comprehensive standards for food fortification, marking the beginning of the "+F Era"

Understanding Food Fortification

Definition and Purpose: Food fortification (FF) is defined as the addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups.⁴

The primary purposes include:

- Addressing Dietary Gaps: Poor choice of food or unhealthy eating habits. leading to micro nutrient deficiencies.
- Targeted Population Support: Risk of micro nutrient deficiencies in women bearing child, young child, the elderly and recovering from illness
- Nutrient Replacement: Fortification restores nutrients lost during food processing and storage.
- Public Health Enhancement: To improve overall nutritional status of the population.

The +F Program:

India's +F program, established by FSSAI, represents a comprehensive approach to food fortification with standardized guidelines, quality assurance mechanisms, and consumer awareness initiatives. The program includes the distinctive +F logo and the Food Fortification Resource Centre, which has been instrumental in building capacity and promoting fortification across the food industry.

Types of Food Fortification Strategies:⁵

Table No.3

S.no	Type	Description	Example
1	Mass Fortification	Nutrients are added to foods commonly consumed by the general population. This strategy is effective when a large proportion of the population is at risk of deficiency.	Iodized salt, vitamin A and D fortified milk
2	Targeted Fortification	Foods intended for specific vulnerable groups are fortified.	Complementary foods for infants and young children, special biscuits, pregnant and lactating women
3	Market-Driven Fortification	Food manufacturer adopts business oriented initiative to add the food with certain micro nutrients Although this sort of fortification is voluntary, the manufacturer must abide by the government set regulatory limits for fortification	Breakfast cereals with added Iron, dairy products (milk) fortified with Vitamin D.

4	Household and Community Fortification	Micro nutrients are added at the household or community level where universal fortification is not feasible.	Multiple micro nutrient powders , soluble tablets etc

Fortification Implementation

1. Selection: Identify the food products that requires fortification based on dietary deficiencies and target populations. Ensure the chosen foods are widely consumed.



2. Nutrient Selection: Choose appropriate Vitamins, Minerals or other nutrients that address the identified deficiencies effectively.



3. Formulation: Develop a fortification strategy that determines the correct dosage and method for adding nutrients without affecting taste or safety.



4. Implementation: Distribute the fortified foods using effective channels and marketing strategies that highlight their nutritional benefits.



5. Monitoring: Continuously evaluate the consumption and health impact of fortified foods to ensure they meet intended outcomes, making adjustments as needed.

Fortification Technique:**Table No. 4**

Technique	Application	Advantage
1. Dry mixing : It involves blending powdered Vitamins and Minerals directly with dry food ingredients. It is a popular choice for large-scale fortification programs.	Flour, salt, powdered beverages	Simple, cost-effective, easy to implement
2. Dissolution in water: Dissolving Vitamins and Minerals in water or oil before adding them to the food. It is particularly useful for fortifying liquid foods and beverages, as well as oils. For instance, vitamin A is often added to cooking oil to help combat Vitamin A deficiency.	Beverages, Cooking oils	Suitable for liquid foods, ensures even distribution
3. Spraying: Coating food particles with a fine mist of nutrient solution. The nutrient solution adheres to the surface of the food particles, providing an even distribution of nutrients.	Cereals, Snacks	Even distribution, suitable for particulate foods.
4. Adhesion : It involves binding micro nutrients to the surface of food particles using a binding agent. The binding agent helps the nutrients adhere to the food particles, ensuring they remain intact during storage and cooking.	Rice and grains	Ensures nutrients remain intact during storage and cooking.

5. Coating: It involves applying a layer of nutrient-rich material to the surface of the food. This method is similar to spraying but often involves a thicker layer of coating. It is commonly used for fortifying rice, where the rice grains are coated with a mixture of vitamins and minerals.	Rice, Cereals	Provides a protective layer, suitable for grains.
6. Pelleting : Involves compressing nutrient-rich ingredients into small pellets that are then mixed with food. This method is often used for animal feed but can also be applied to human foods such as fortified rice. The pellets ensure a consistent and controlled release of nutrients.	Animal feed, fortified rice	Consistent nutrient release, suitable for bulk foods

Regulatory Framework and Standards

FSSAI Regulations 2016:

1. A significant milestone in India took place in October 2016 when the food safety standard authority of India published draft standard for food fortification.
2. The draft for wheat flour fortification is in line with global fortification recommendation for Iron, Vitamin B12 and Folic acid.
3. These regulation set the standards for food fortification and encourage the production, manufacture, distribution, sale and consumption of fortified food.
4. The FSSAI drafted guidelines for the fortification of food that include, rice, wheat flour, milk, salt and edible oil.
5. They also provided for a specific role of FSSAI in the promotion for food fortification and making fortification mandatory.

Government-Supported Fortification Programs:

1. Fortification of ICDS supplementary cooked food.
2. Fortification of food for the Mid Day Meal.
3. Fortification of factory produced Ready-to-Eat (RTE) food.
4. Fortification of wheat flour supplied through Targeted Public Distribution System (TPDS).
5. Under the prevention of Food Adulteration Act 9(PFA), The food Safety and Standards Act (FSSA) voluntary fortification guidelines are given for :

whole wheat flour(Atta) and
Refined wheat flour (Maida).

Integration with Traditional Knowledge Systems:

Ayurveda provides valuable principles for enhancing food quality and personalization of nutrition. *Acharya Kashyapa* emphasized that no medicine is superior to food and stated that proper diet alone can help maintain health.⁶ Ayurveda sees food not just as fuel, but as a tool to build *Ojas* support *Agni* and maintain *Dosha* balance.⁷ Fortification is not just nutrient addition, but health enhancement and Ayurveda also emphasizes on enhancing food quality. According to modern science fortification is adding specific nutrients to address deficiencies according to Ayurveda it is enhancing the natural potency of food using herbs, spices and processing methods .Combining both approaches can lead to sustainable, culturally and bio available accepted nutrition strategies. Examples:

1. *Ksheera + Haridra*: Enhances immunity and provides anti-inflammatory effects.
2. *Ghrita+ Triphala*: Supports digestive health and detoxification.
3. *Takra + Jeeraka + Adraka*: stimulates digestion.
4. *Bhojana Patra*: Preparation of formulations in metallic vessels such as Iron, Copper or Bronze may enhance therapeutic properties through metal ion interactions.

Advantages and Limitations:

Advantages:

1. Food fortification reduces the prevalence of micro nutrient deficiencies.
2. Helps to improve dietary and nutritional status of an individual.
3. It is one of the most cost effective procedures that can be executed on a bigger scale.
4. The amount of micro nutrient added to the food is little and all around managed. Thus, probability of an overdose is far fetched..
5. Does not require an adjustment in the individual and utilization design.
6. It is planned in such a way that the intrinsic characteristics of the food such as the taste, the appearance and the texture are not altered.
7. Fortification programs can be implemented rapidly.

Limitation:

1. Food fortification may overshadow the importance of dietary diversity.
2. It is considered as a long term solution to micro nutrient deficiency.
3. It involves extensive expenses in the process.
4. In some foods, the shelf life of food is reduced due to fortification.
5. The manufactures may fortify highly junk and relatively unhealthy foods in order to attract the consumers .These foods may have more negative health effects than the positive effect.

Food Vehicle Fortification Matrix:

Choosing a food vehicle and fortificant:

1. The food should be consumed by all population groups that are at risk of the particular nutritional deficiency.
2. The food should be used regularly and in consistent amount by the entire population at risk.
3. Taste appearance and smell of the food should not change after fortification.
4. The fortificant should remain stable under extreme conditions of cooking, food processing, delivery and storage.
5. The fortificant should not increase the cost of food.
6. The food should not be consumed in amount that would present a risk of consumption at toxic levels of fortificant.

Common Fortification Vehicles:

1. Common Salt: Iodine and Iron fortification
2. Wheat Flour: Iron, Folic acid, Calcium, Zinc, Vitamins A and B
3. Rice: Iron, Folic acid, Calcium
4. Cooking Oils: Vitamin A and D
5. Sugar: Vitamin A
6. Mineral Water: Various micronutrients
7. Milk and Dairy Products: Vitamin A and D, Iron, Folic acid, Calcium, Omega-3, 6 fatty acids
8. ICDS Supplementary Foods: Iron, Folic acid, Calcium, Zinc

Program Coverage and Impact: The fortification of staple foods ensures broad population coverage and particularly benefits vulnerable groups through government safety net programs including ICDS, Mid-Day Meals, and TPDS.

Future Directions and Recommendations: Based on the comprehensive review of food fortification strategies and implementation, the following recommendations emerge for future action -

Table No. 5

Policy and Regulatory Enhancements	Industry and Market Development
1.Strengthen and harmonize national fortification standards with international guidelines	1. Encourage private sector participation through tax incentives and technical support
2.Implement mandatory fortification for all major food vehicles	2. Develop local fortification technology capacity and expertise
3.Establish robust monitoring and enforcement mechanisms	3.Create market incentives for fortified food products

4.Develop clear labeling requirements and consumer protection measures	4.Establish quality assurance and certification systems

Effectiveness/ Results of fortification:

1. Iodization of salt for combating Endemic Goiter
2. Fluoridation of water to prevent Dental Caries

The India's +F program highlights the effectiveness of large-scale fortification initiatives when supported by strong political commitment, comprehensive regulatory frameworks, and multi-sector partnerships. The program's emphasis on quality standards, consumer awareness, and industry capacity building provides a valuable model for other countries.

However, the challenges identified highlight the complexity of implementing sustainable fortification programs. Technical barriers related to nutrient stability require ongoing research and innovation. Regulatory challenges necessitate strong institutional capacity and enforcement mechanisms. Public acceptance issues require culturally appropriate communication strategies and community engagement.

The integration of traditional knowledge systems with modern fortification science offers promising avenues for enhancing program effectiveness and cultural acceptability. The *Ayurvedic* emphasis on food as medicine and traditional processing methods can complement modern fortification approaches.

Future success will depend on addressing these challenges through:

1. Enhanced Multi-Sector Collaboration: Partnerships between government, industry, civil society, and international agencies
2. Technological Innovation: Advanced delivery systems and monitoring technologies
3. Sustainable Financing: Long-term funding mechanisms and public-private partnerships
4. Comprehensive Monitoring: Real-time data collection and impact assessment
5. Community Engagement: Culturally appropriate communication and behavior change strategies

Conclusion

Food fortification is a cost-effective intervention with great potential to address malnutrition globally. Studies on the fortification of foods have shown positive results not only in the control and prevention of micronutrient deficiencies among vulnerable populations, especially women and children, but also along social, economic and environmental dimensions. Sight and Life projects offer successful examples to address micronutrient deficiencies through fortification from several LMICs and emphasize the importance of multidimensional partnerships in addressing the many challenges of food fortification strategies. Fortification is not a standalone solution but a key component of a broader nutritional strategy.

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