

Spray fortification is a fortification method that involves the application of liquid micronutrient solutions on the surface of food products. This fortification method is commonly practiced for the fortification of rice, cereals, and snack foods. Spray fortification allows for precise dosing of micronutrients and is particularly useful when fortifying individual food units. However, it requires specialized equipment and handling to ensure nutrient stability.

Extrusion technology is an advanced fortification method widely practiced in the production of fortified rice kernels and ready-to-eat breakfast cereals. In this process, micronutrients are mixed with food ingredients and processed under controlled temperature and pressure conditions to produce fortified products with uniform nutrient distribution. Extrusion technology improves nutrient retention, product quality, and allows for the simultaneous addition of multiple micronutrients, making it an ideal technology for large-scale fortification programs.

Micronucapsulation is an advanced fortification technology that involves the encapsulation of micronutrients within protective coatings or capsules. This technology improves the stability and bioavailability of labile nutrients such as iron, iodine, and vitamins by protecting them from heat, moisture, oxygen, and undesirable interactions with other food components. Micronucapsulation also helps to mask unpleasant tastes or odors, thereby improving consumer acceptability while ensuring effective nutrient delivery.

2.3 Commonly Fortified Foods and Nutrients

Food Vehicle	Nutrients Added
Salt	Iodine
Wheat flour	Iron, folic acid, vitamin B ₁₂
Milk	Vitamin A, D
Edible oils	Vitamin A, D
Rice	Iron, zinc, folic acid

3. BIOFORTIFICATION

3.1 WHAT IT'S ABOUT

Biofortification, as a form of nutrition enhancement, refers to increasing the concentration of essential vitamins and minerals right inside the crops as they are growing, not after they are harvested. By leveraging a growing crop's genetic capacity or response to specific minerals, it is possible to enhance the quality of these micronutrients that will reach people's plates by increasing them at their source.

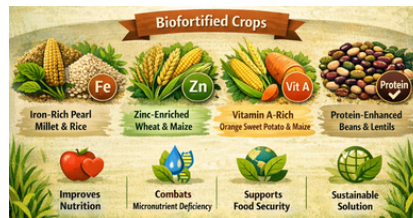
Biofortification is an important tool for incorporating more nutrient-dense crops into people's diets, particularly among persons living in resource-constrained settings who might not have access to fortified foods or a variety of nutrients. This approach is a cost-effective, long-term solution for enhancing nutrition, security, and health among a population without requiring significant diet modification or practice change at a community level.

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INTRODUCTION

Adequate micronutrient intake is vital for healthy growth, effective immunity, brain development, and overall human health. Micronutrients such as iron, iodine, zinc, vitamin A, and folic acid are of prime importance for metabolic processes, disease resistance, and physical and mental development. In many developing and transition countries, the diet consists mainly of staple foods, which are high in calories but low in the required micronutrients. This type of diet causes micronutrient deficiencies on a large scale, known as "hidden hunger," especially among women of reproductive age, infants, children, adolescents, and other at-risk groups.

Micronutrient deficiencies are major contributors to public health issues such as anemia, growth and development problems, immune deficiency, reduced work productivity, and higher morbidity and mortality rates. Eradication of micronutrient deficiencies through dietary diversification is often difficult because of economic limitations, unavailability of food, and food habits. In this scenario, food fortification and biofortification have proven to be effective and economical approaches. These methods enhance the nutritional content of staple foods without the need for significant changes in food habits, making them effective approaches to counter micronutrient-related malnutrition on a large scale.



2. Food Fortification

2.1 Concept and Types

Food fortification can be defined as the intentional addition of one or more key micronutrients to food products during processing to enhance their nutritional quality and address specific micronutrient deficiencies in the population. Food fortification is recognized as one of the most effective approaches to improving public health nutrition because it utilizes existing food infrastructure and reaches a large portion of the population through commonly consumed foods. Food fortification can be categorized based on the target population and approach to implementation. Mass food fortification involves the addition of micronutrients to staple foods commonly consumed by the general population, such as iodized salt, iron-fortified wheat flour, and vitamin A-fortified edible oils. Mass fortification is very effective in reaching a large portion of the population. Targeted fortification is implemented to address the nutritional requirements of specific population groups, such as infants, preschool-age children, pregnant women, or school-age children, through products such as fortified complementary foods or supplementary nutrition programs. Market-driven fortification, also known as voluntary fortification, is implemented by the food industry, which adds micronutrients to commercial food products to improve nutritional quality and marketability, although government regulation is required to ensure safety and efficacy.

2.2 Technologies Used in Food Fortification

The effectiveness of food fortification largely relies on the use of appropriate technologies that ensure the uniform distribution, stability, bioavailability, and consumer acceptability of the added micronutrients.

Dry blending is one of the simplest and most widely practiced fortification methods. In this method, micronutrient premixes in powder form are well mixed with dry food substrates such as wheat flour, maize flour, sugar, and salt. Dry blending is an inexpensive, simple, and large-scale fortification method. However, it requires proper quality control to ensure uniform mixing and prevent nutrient losses during storage.

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कोटा, राजस्थान



Food fortification and biofortification: Technologies and health impact

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3.2 The main methods

Agronomic Biofortification: This method involves using mineral-dense fertilizers to increase the concentration of minerals present in the produce. This method increases the plant's power to absorb minerals. For example, using zinc-dense fertilizers in wheat increases the zinc content. Moreover, it increases wheat yields. This method is fast and flexible, particularly when some minerals are absent in the soil.

Conventional Breeding: This method, which is widely used, reasonably priced, and popular with consumers, finds crop varieties with the ability to store more micronutrients. It then crosses these crop varieties with high-yielding crop varieties. This method, which also occasionally results in iron-rich pearl millet, zinc-rich rice, and zinc-enriched wheat, is friendly to the environment and does not involve any genetic engineering.

Genetic engineering and Biotechnology: This method involves adding specific genes that are linked with the production or quantity of nutrients. This method is beneficial when the crop does not have enough variation in the specific nutrient. A well-known example of genetic engineering is the development of Golden Rice. This rice variety is engineered to produce beta-carotene, an important nutrient in vitamin A production. This method has proved effective but has to meet safety standards before it is put into practice.

3.3 Biofortified Crops

Several biofortified crops have been successfully developed and promoted to address micronutrient deficiencies worldwide. Iron-rich rice and pearl millet varieties help combat iron deficiency anemia, particularly among women and children. Zinc-enriched wheat and maize contribute to improved immune function and child growth. Vitamin A-rich sweet potato and maize play a crucial role in preventing vitamin A deficiency, which is a leading cause of childhood blindness. Additionally, protein-enhanced legumes improve dietary protein intake, especially in vegetarian and low-income populations, thereby supporting overall nutritional adequacy.

4. Health Impact of Fortification and Biofortification

4.1 Reduction of Micronutrient

Fortification and biofortification of foods have recorded significant successes in the reduction of micronutrient gaps in various countries and populations. Universal salt iodization has led to significant reductions in iodine-based deficiency diseases like goiter and cognitive impairments. Fortification of foods and iron-rich biofortified crops likewise have recorded significant reductions in iron-deficiency anemia among women and children. In the same vein, vitamin A-rich foods, as well as biofortified crops, have been fundamental in reducing vitamin A deficiency and associated diseases like night blindness and child mortality.

4.2 Improved Maternal and Child Health

Sufficient micronutrient intake includes iron, folic acid, zinc, and vitamin A. These micronutrients support a healthy pregnancy as well as child development. They also ensure improved pregnancy outcomes. Improved pregnancy outcomes include reduced anemia in mothers, birth complications, as well as low birth weight. Improved micronutrient status in children results in better physical growth and development. It also promotes better cognitive development as well as improved cognitive learning.

4.3 Enhanced Immunity and Disease Resistance

Micronutrients such as zinc and vitamin A are very important for the maintenance of a robust immune system. Thus, the uptake of fortified and biofortified foods helps to enhance the immunity of the body against infections. Enhanced immunity has positive impacts on the health of the public.

4.4 Economic and Social Benefits

These benefits go beyond nutritional health benefits, as more nutritious diets translate into greater physical productivity, better learning outcomes, and greater work efficiency, leading to increased incomes for households and countries as a whole. In addition, less disease resulting from nutritional problems lightens the burden on healthcare systems, while these efforts can help ensure food and nutrition security, as well as sustainable agriculture and social equity, through support to vulnerable and marginalized groups.

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5. Challenges and Limitations

Despite the benefits of food fortification and biofortification, there are challenges associated with their effectiveness, particularly due to nutrient loss in processing, storage, and especially through cooking methods, especially with heat-labile vitamins A, folic acid, and vitamin C, as they are particularly susceptible to loss when storage conditions involve exposure to light, moisture, and longer storage duration.

The issue of bioavailability is a major barrier as well. The presence of anti-nutritional factors that are commonly found in most foods, such as phytates, oxalates, and polyphenols, affects their intake for certain minerals that are essential, such as iron and zinc. The extent to which fortified nutrients are used is also based on an individual's health, variety of diet, and the way different nutrients react.

Another thing to be considered is regulatory and quality control barriers. For instance, sustaining consistency in the level of fortification, ensuring that the foodstuff is safe for use, and enforcing regulations among food producers require effective regulations. Developing countries face challenges in developing infrastructures to support effective QA.

Similarly, consumer awareness and acceptance also hold equal significance, particularly regarding biofortified or genetic-engineered foods. Misconceptions about fortified foods, lack of nutrition education, and associated apprehensions regarding taste, appearance, or safety can affect the adoption of these foods as well.

Further, the investment required in terms of research and development before commercialization could be considered another constraint, especially where biofortification is concerned. For example, research requires enough investment in terms of plant breeding, biological technology, field research, etc., which can act as a constraint, mainly for public institutions and other small players in the private sector.

6. Future Prospects

Looking into the future of fortification and biofortification, the potential relies on the integration of latest technologies with innovative nutrition inputs. Nanotechnology holds promise as an opportunity to enhance the stability of nutrients, facilitate their delivery, and improve accessibility using techniques such as nano-encapsulation. Improving the utilization of fortified foods with such technologies can make a dramatic impact.

Climate resilient and nutrient-dense crops will probably assume greater significance as the climate continues to change. Crops that offer a combination of nutritive values and tolerance to climatic stresses such as drought, heat, salt, and pests will undoubtedly play an important role in ensuring nutrition security.

Public-private partnerships would play an important role in scaling up fortification and biofortification efforts. Partnerships among different institutions, such as food companies, research institutions, and governments, would hasten research, reduce costs, and increase access to nutritious foods for everyone. Partnerships would also enhance supply chain and distribution efforts.

The presence of robust support for policy can provide encouragement to bring about its overall impact. The implementation of mandatory fortification programs can ensure overall impact. The international goals can provide overall encouragement.

Digital monitoring and traceability are envisioned to improve transparency, accountability, and quality management in fortified food programs. Technologies such as blockchain technology, mobile tracking, and real-time data analysis have the potential to improve the management of nutrient levels and fortified food supply chains.

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CONCLUSION

Fortification and biofortification are powerful tools that are used synergistically to address micronutrient-related malnutrition and hidden hunger. While immediate human health benefits are realized from commonly consumed fortified foods, this concept ensures a long-term solution. Thus, it makes a great contribution to public health while strengthening food and nutrition security. Fortification and biofortification are expected to move to centre stage with advancements that are likely to come from continued technology innovations, robust policies, and increased public awareness. They will ensure sustainable development goals for building a healthier future for all.

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