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Innovative Approaches to Nutrient Fortification in Dairy Foods

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Milk is a unique nutritionally balanced dietary source, but processing and storage can affect its nutrients. With a growing focus on personal health, consumers seek nutritious and flavourful foods, leading to increased interest in fermented milk. Functional ingredients enhance their market appeal, aligning with consumer preferences for health-promoting products. The science of food and health emphasizes how nutrients support body growth, development, and maintenance, according to WHO. Micronutrient deficiencies affect billions globally, with nearly half of India's population affected. Iron and zinc deficiencies are widespread, impacting immunity and cognitive development. Addressing these gaps, especially through food fortification, is vital for global health improvement. Food fortification, along with diet diversification and supplementation, is crucial for tackling nutrient deficiencies. Dairy products, being widely consumed and affordable, are ideal for fortification. Adding micronutrients to milk enhances its nutritional value, promoting better health and balanced diets for consumers seeking both flavour and nutritional benefits.

Status of micronutrient deficiency in the world

Micronutrient deficiencies affect billions globally, known as "hidden hunger." Iron and zinc deficiencies are widespread, impacting immunity and cognitive function. Other nutrients like vitamins A and D, calcium, magnesium, and copper are also deficient. Vulnerable groups, like children and pregnant women, are particularly at risk, facing long-term health issues. Strategies like food fortification are vital for addressing this global health challenge. Micronutrient deficiencies impact over two billion people globally (add reference), and hinder proper growth and development. This further leads to various health issues and reduces productivity. Addressing these deficiencies is crucial for improving the health and developmental outcomes of individuals globally.

History and development

The history of micronutrient fortification reflects its critical role in enhancing global public health. In 1920, Switzerland pioneered the efforts by introducing salt iodization to combat iodine deficiency. In 1933, the USA followed suit with the first fortification of milk with vitamin D, aiming to prevent rickets. During the 1940s, Britain and USA began enriching flour to improve overall nutritional status and reduce deficiencies of essential vitamins and minerals. In 1954, India added vitamins A and D to Vanaspati, a type of hydrogenated vegetable oil, to address widespread deficiencies in these nutrients. By 1962, the FDA in the United States had established regulations to limit fortification, ensuring that nutrient levels were safe and effective. Innovations continued into the 21st century. In 2008, Simova developed iron-fortified Bulgarian yoghurt, addressing iron deficiency anaemia. In 2013, Karaaslan and his colleagues created phenolic-fortified yogurt using grape and callus extracts, enhancing the antioxidant properties of the yoghurt. Most recently, in 2018, Marapana developed an omega-3 fortified ice cream using flaxseed oil, offering a delicious way to increase the intake of essential fatty acids. These advancements illustrate the ongoing efforts to improve nutrition and health through food fortification.

Mandatory Fortification Regulated by FSSAI

The Food Safety and Standards Authority of India (FSSAI) mandates the fortification of several key food products to address widespread nutrient deficiencies. The following table outlines these products and the required nutrients for fortification:

These regulations ensure that commonly consumed food items contribute significantly to the daily nutrient intake of the population, thereby addressing deficiencies and improving overall public health.

Classification of food fortification

Food fortification encompasses mass fortification, biofortification, and home fortification. Mass fortification involves adding essential nutrients to staple foods on a large scale, typically mandated by government regulations. Biofortification focuses on breeding crops to naturally contain higher levels of specific nutrients. Home fortification involves individuals adding nutrient powders or supplements to their foods at home to enhance their nutritional content. Each method addresses nutrient deficiencies in different settings and populations.

Table 1 Food products in which mandatory fortification is regulated by FSSAI

Food Product	Nutrients for Fortification	Recommended level of fortification
Milk (per litre)	Vitamins A and D	270 – 450 µg RE (vit A) 5-7.5 µg RE (vit D)
Edible Oil (per gm)	Vitamins A and D	6 µg RE - 9.9 µg RE (vit A) 0.11 µg– 0.16 µg (vit D)
Wheat Flour (per kg)	Iron, Folic Acid, Vitamin B12	28 mg- 42.5 mg (Iron), 75 µg- 125 µg (Folic acid) 0.75 µg- 1.25 µg (vit B12)
Rice (per kg)	Iron, Folic Acid, Vitamin B12	28 mg- 42.5 mg (Iron) 75 µg- 125 µg (Folic acid) 0.75 µg- 1.25 µg (vit B12)
Salt	Iodine (Potassium Iodate) (on a dry weight basis)	(a) Manufacture level: 20-30 ppm (b) Distribution including retail level channel: 15-30 ppm
	Iron (Ferrous sulphate or Ferrous Fumarate)	850-1100 ppm

Common fortification methods used in the food industry

Micronutrient Fortification involves adding essential vitamins and minerals to food products to enhance their nutritional value. For example, adding vitamin D to milk or iodine to salt. Micronutrient fortification helps address micronutrient deficiencies in populations. Iron fortification is particularly important in addressing iron deficiency anaemia, a common nutritional problem worldwide. Iron can be added to foods such as cereal, flour, and infant formula. Folic acid fortification in foods such as flour, bread, and cereals to prevent neural tube defects in newborns and reduce the risk of folate deficiency in the population. Calcium Fortification to foods like orange juice, soy milk, and cereals to improve bone health and prevent conditions like osteoporosis. Iodine is added to salt to prevent iodine deficiency disorders, such as goiter and intellectual disabilities. Vitamin D is added to foods like milk, orange juice, and breakfast cereals to prevent vitamin D deficiency, which can lead to bone disorders such as rickets in children and osteomalacia in adults.

The fortification of food products is a pivotal strategy in addressing micronutrient deficiencies and enhancing public health. This article explores the prevalent fortification methods used in the food industry, focusing on direct fortification, emulsification, and microencapsulation of mineral salts or vitamins.

Direct Fortification

It is one of the simplest and most widely used methods, involving either dry blending or wet mixing. Dry blending incorporates powdered vitamins and minerals directly into dry products like flour, cereals, and powdered milk, ensuring even distribution and stability of the nutrients (Institute of Medicine, 2003). Wet mixing, on the other hand, involves adding nutrients to liquid foods such as beverages and dairy products during processing, allowing for the integration of water-soluble vitamins and minerals (Hettiarachchy *et al.*, 2012). For instance, milk is often fortified with vitamins A and D to enhance its nutritional profile.

Emulsification

It is a technique used to incorporate oil-soluble vitamins, such as A, D, E, and K, into water-based food products. This method employs the creation of stable emulsions through mechanical processes or the use of emulsifiers. Ultrasonic emulsification, in particular, uses ultrasonic waves to produce fine, stable emulsions that improve the bioavailability and stability of the incorporated nutrients (Kentish & Feng, 2014). This technique is often used in the fortification of dairy products, beverages, and sauces.

Microencapsulation

It involves enclosing vitamins and minerals in microscopic capsules, which can protect the nutrients from degradation and control their release in the body. This method is particularly beneficial for fortifying food products that undergo high-temperature processing or have long shelf life (Gibbs *et al.*, 1999). For example, iron and zinc can be microencapsulated to prevent their interaction with other food components, which might otherwise affect the food's taste, appearance, or stability. Additionally, microencapsulation can mask the taste and odour of certain vitamins, making them more palatable in fortified foods (Onwulata, 2005).

Biofortification

It is another significant method, involving the breeding of crops to naturally enhance their nutrient content. This approach can be achieved through conventional breeding techniques or genetic modification, resulting in nutrient-dense crops such as iron-rich beans and vitamin A-enriched golden rice (Bouis & Saltzman, 2017). Biofortification aims to improve the nutritional value of staple crops, thereby addressing micronutrient deficiencies at a population level.

Spraying and Coating

Techniques are commonly used for ready-to-eat cereals and snacks, where foods are sprayed or coated with nutrient-rich solutions, ensuring even distribution of the added nutrients (Onwulata, 2005). This method is efficient for fortifying products that are consumed directly without further processing.

Fermentation

It utilizes beneficial microorganisms to increase the nutrient content of foods. For example, fermenting dairy products with probiotics can enhance levels of vitamins B_{12} and folate, thereby improving their nutritional value (Tamang *et al.*, 2010).

Extrusion

Is primarily used for cereal products. This method involves processing the food mixture through a die under high pressure and temperature, allowing for the uniform incorporation of nutrients (Guy, 2001). Extrusion can enhance the texture and digestibility of fortified foods while ensuring consistent nutrient distribution.

Vacuum Impregnation

It involves placing food in a vacuum chamber and infusing it with a nutrient-rich solution. This technique is particularly effective for fortifying fruits and vegetables, allowing for deep penetration of nutrients into the food matrix (Fito & Chiralt, 1996). These fortification methods collectively enhance the nutritional quality of food products, contributing to the alleviation of nutrient deficiencies and promoting better health outcomes on a global scale.

Conclusion

Innovative approaches to nutrient fortification in dairy foods offer promising avenues for enhancing the nutritional value of these products. By strategically adding essential vitamins and minerals such as vitamin D, calcium, and probiotics, dairy manufacturers can address the specific nutritional needs and preferences of consumers. These fortification methods not only contribute to improved bone health, gut health, and overall wellness but also play a crucial role in combating nutrient deficiencies in populations worldwide. Moreover, ongoing research and technological advancements continue to drive the development of novel fortification techniques, ensuring that dairy foods remain a vital component of a balanced and nutritious diet. As the food industry evolves, the integration of innovative fortification methods underscores a commitment to promoting public health and well-being through accessible and fortified dairy products.

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