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9. Introduction to Food Fortification

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Abstract:

The chapter "Introduction to Food Fortification" provides a comprehensive overview of the process and significance of enhancing food products with essential micronutrients to combat nutritional deficiencies. It explores the historical development and global adoption of food fortification, highlighting its role as a critical public health strategy. The chapter discusses the chemical forms and recent advancements in fortifying key nutrients such as iron, iodine, vitamin A, folic acid, and vitamin D. It emphasizes the importance of fortification in improving health outcomes, particularly in populations with limited access to nutrient-rich foods. The text also addresses the benefits and limitations of fortification, including its cost-effectiveness, potential impacts on food quality, and the challenges of ensuring equitable access. The need for ongoing monitoring and quality assurance to maintain the efficacy and safety of fortified foods is underscored. Overall, the chapter advocates for integrating fortification with broader nutritional interventions to achieve sustainable improvements in public health.

Keywords:

Food fortification, micronutrients, macronutrients, health, deficiencies.

9.1 Introduction:

Fortification is the function of improving the stability of the substance. In the context of food, “Fortification” relates to enhancing the nutritional condition of food products by expanding the status of specific nutrients (Barbara Poniedziałek, 2020).

Minerals like iron and iodine, as well as vitamins like folate, D, and A, are usually fortified nutrients. Forwarding widespread dietary deficiency in populations is the main goal, mainly in areas where diets are lacking in key nutrients. The motive of this approach is to boost public health outcomes by increasing the utilization of vital micronutrients through foods that are frequently overwhelming. The careful addition of some microelements to food products to enhance their content, prevent certain deficiencies, and offer health advantages is known as fortification, according to the World Health Organization (WHO) (Barbara Poniedziałek, 2020). Food fortification, involving adding important minerals and vitamins to commonly consumed foods, is an integral public health strategy to treat the widespread deficiencies in nutrition that are currently occurring. The technique, which goes as far as the early 20th century, has spread over the world and significantly enhanced health outcomes in countries that are both industrialized and developing. To implement food fortification into the systems of food production and distribution, foods that are commonly eaten that are strategically processed must first be determined (Wesley, October 2016). The food product pyramid, frequently referred to as the food pyramid, is a graphic that illustrates the appropriate daily consumption of every kind of food and groups multiple food groups to help people comprehend how to sustain a balanced diet. Due to the reality that staple foods tend to be used for producing basic and value-added foods, supplementing foods at the base of the hierarchy has a greater chance of fortifying products through the other levels (Wesley, October 2016). This introduction will go into great length about the chemical forms and recent developments of iron, iodine, vitamin A, folic acid, and vitamin D—the five key fortified nutrients (Zimmermann, M.B.2009). This type of strategy is especially critical in areas with monotonous diets and inadequate access to foods that are rich in nutrients (Harrison, E. H. (2005). To guarantee the stability, bioavailability, and effectiveness of these enhanced nutrients, it is important to understand their chemical composition (Gupta, R. P., & Hollis, B. W. (2009). To enhance public health outcomes, recent advances in food fortification have been focused on optimizing all of these elements. Here, we look into the chemical composition in addition to current developments in the fortification of iron, iodine, vitamin A, folic acid, and vitamin D—five vital minerals (Lietz, G., & Henry, C. J. (2000).As wheat constitutes one of the few crop species that are widely farmed as staple food sources, its nutritional value is greatly significant(Zuzana Šramkováa*, 2009).

Food fortification is a significant public health intervention that enhances overall health, supports vulnerable populations, addresses widespread micronutrient deficiencies, and offers an effective and scalable way to improve nutritional quality and carry out national and international health goals.

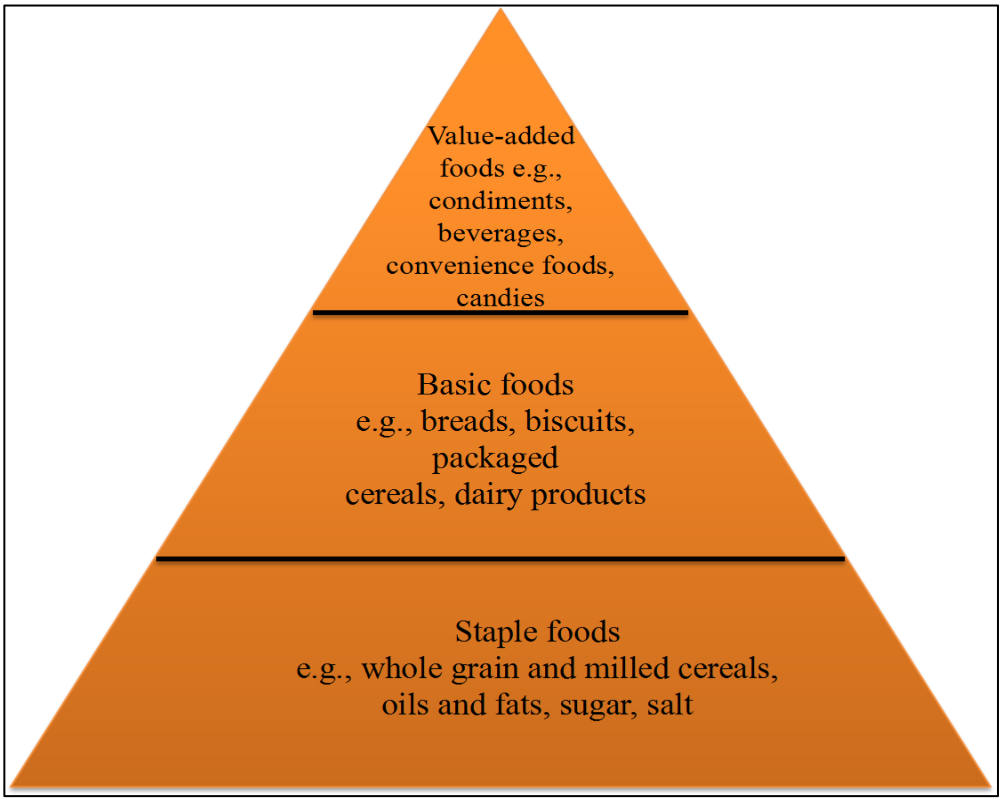

Figure 9.1: Food Product Pyramid(Wesley, October 2016).

9.2 Different Types of Food Fortification:

There are three types of food fortifications. The detailed overview is as below:

9.2.1 Commercial Fortification

Commercial fortification is the process of enhancing the nutritional value of regularly consumed foods by adding essential vitamins and minerals. It encompasses three major categories: mass fortification, targeted fortification, and market-driven fortification(Harris 2019).

Mass fortification involves adding nutrients to widely consumed staple foods like flour and salt to benefit the general population(Hefferon 2015). Targeted fortification aims at specific groups, such as adding iron to foods for pregnant women or children.

Market-driven fortification is led by consumer demand, often seen in products like breakfast cereals or energy bars, where manufacturers add nutrients to appeal to health-conscious buyers. This strategy helps address nutrient deficiencies and improve public health on a broad scale(Allen 2006).

A. Mass Fortification:

It is a process wherein nutrients are added to staple foods consumed by a large proportion of the population(Soekarjo and Zehner 2011). This measure is taken when there appears a growing trend in spreading nutrient deficiencies in a country or region. Examples include:

Salt Iodization: Addition of iodine in table salt to avert an iodine deficiency disorder, such as goitre and intellectual disabilities(De-regil et al. 2011).

Rice Fortification: This involves the enrichment of rice with iron, folic acid, and vitamin A to help in several micronutrient deficiencies(Poletti, Gruissem, and Sautter 2004).

B. Targeted Fortification:

It refers to the inclusion of specific population groups that have an unusually high risk of deficiency for one or more nutrients. In this type of fortification, nutrition is targeted for improvement among at-risk populations(Maciej Serda et al. 2013). Examples include:

Complementary Foods: Fortified foods for young children, such as porridges and snacks, are enriched in iron, zinc, and vitamins to meet nutritional gaps associated with weaning(Neufeld, Osendarp, and Gonzalez 2017).

Pregnancy Supplements: These are the fortified products that help in pregnancy, such as prenatal vitamins containing folic acid, iron, calcium, and DHA, all of which are important for both maternal and fetal health(Yang and Huffman 2011).

C. Market-Driven Fortification

It is the addition of nutrients to food products as a part of the marketing strategy for selling to health-conscious consumers. This type of fortification is normally practisedvoluntarily because it is driven by health-conscious consumer demand(Klassen-Wigger and Barclay 2018).

Examples include:

Breakfast Cereals: Many breakfast cereals are enriched with a variety of vitamins and minerals, including added iron, the B group, and vitamin D for those more health-conscious shoppers(Wiemer 2018).

Fortified beverages: Orange juice fortified with calcium and vitamin D, or plant-based milk alternatives fortified with B12 and vitamin D(Berry Ottaway 2009).

9.2.2 Home Fortification:

Home fortification involves mixing essential vitamins and minerals directly into foods prepared at home, often through products such as micronutrient powders or lipid-based nutrient spreads. This approach is useful in low-income settings where there is a likelihood of dietary diversity being low(Suchdev et al. 2020). For examples:

Micronutrient Powders (MNPs): Single-dose packets of vitamins and minerals, added to home-cooked foods, fortified with a powder of multiple micronutrients. Mainly for children, to combat iron deficiency, anaemia, and other problems associated with micronutrient deficiency. Very easy to use—can be incorporated into regular meals without too much interference with taste or appearance(Salam et al. 2013).

Fortified Spreads and Pastes: These are concentrated spreads or pastes, often nutrient-dense, spread, or paste, and usually used as a response in emergencies, mostly for severely malnourished children (Matilsky et al. 2009).

Examples include lipid-based nutrient supplements, which provide a concentrated source of calories, protein, and essential micronutrients—such as Plumpy'Nut.

Biofortified Crops: Plants bred to have an increased content of certain nutrients such as vitamin A in sweet potatoes or iron in beans. Such bio-fortified crops, when consumed, therefore, can improve nutrient intake as part of the daily diet without extra fortification products(Bouis et al. 2011).

9.2.3 Bio-Fortification:

Bio-fortification is the process of breeding crops with increased levels of required vitamins and minerals to improve public health.

This will help in curbing micronutrient deficiencies, especially where staple crops are major components of the diet(Bouis and Saltzman 2017). Types of Bio-fortification include:

A, Conventional Breeding:

Crop breeding programs are involved in selective breeding for producing nutrient-rich crop varieties.

Examples include high-iron beans that can elevate the level of this element, zinc-enriched rice, and beta-carotene-rich orange-fleshed sweet potatoes(Jere et al. 2016).

B. Genetic Engineering:

These techniques are used to improve the nutritional profile of crops. Someare Golden Rice with beta-carotene and iron bio-fortified rice.(Tang et al. 2009)

C. Agronomic Practices:

Soil and foliar applications of micronutrients can enhance nutrient intake in crops.

For instance, applying zinc fertilizers in the soil can increase the content of zinc in crops such as wheat(Poletti et al. 2004).

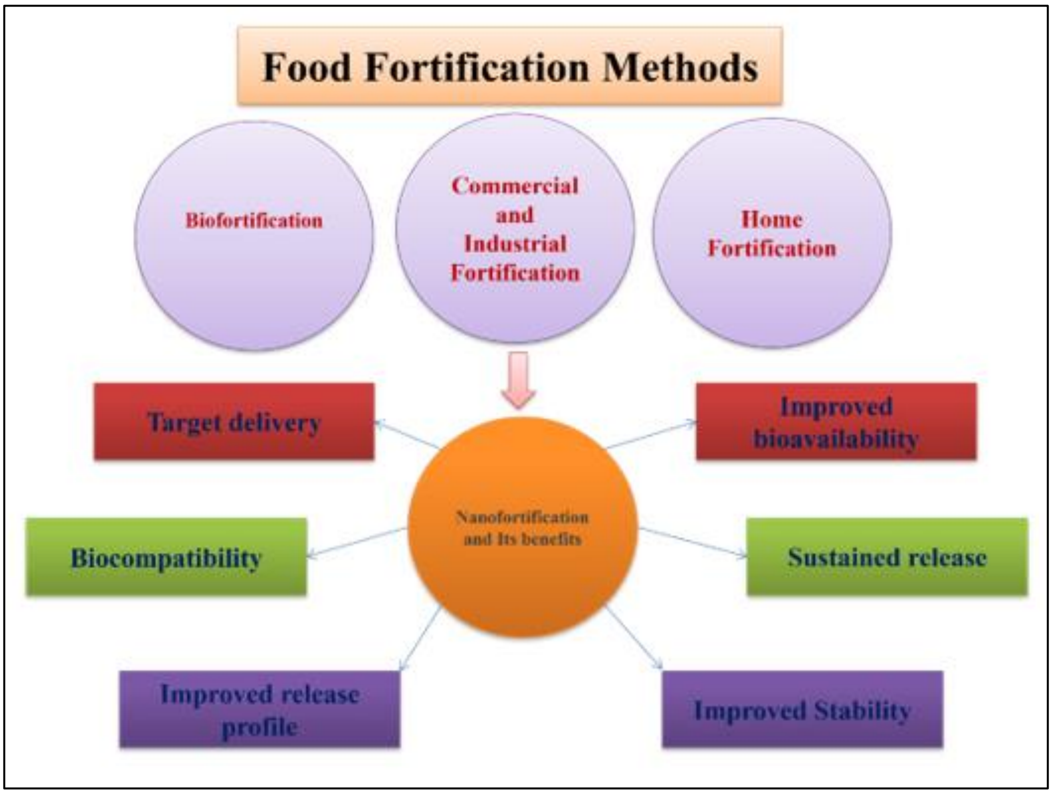

Figure 9.2: An illustration of The Trending Fortification Methods (a, · March 2022)

9.3 Nutrients:

Nutrient fortification plays a very crucial role in our lives by improving public health and labelling the nutrition deficiencies in inhabitant's health. Fortification is a methodical process that is grounded in scientific investigation. Professionals analyse the nutrients that people's diets are deficient in and the health issues that are related to these deficiencies. For instance, salt is frequently fortified with iodine to prevent thyroid diseases in areas where a large number of people do not obtain enough of this vitamin, which is essential for thyroid function. The technique of supplementing foods and beverages containing vital vitamins and minerals is commonly referred to as nutrient fortification. A nutrition addition program's efficacy depends on whether the food containing the targeted nutrient(s) will be accepted, consumed by those who want or desire it, and available at a price they can pay(RICHARDSON, 1990). There are two types of nutrients. They can be broadly categorized into macronutrients and micronutrients.

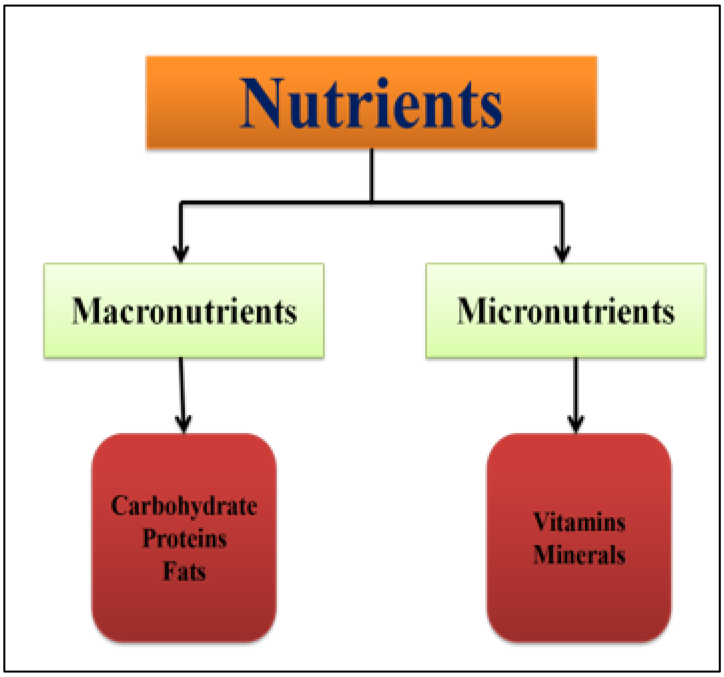

Figure 9.3: Types of Nutrients

Macronutrients are crucial components of food that provide us energy and are required by the human organism in relatively big proportions. They are composed of proteins, lipids, and carbohydrates; each of them serves a specific function in supporting various kinds of biological functions (Mann, J., & Truswell, S. (Eds.). 2017).

Carbohydrates are mainly found in foods such as grains, fruits, vegetables, and dairy products. Simple sugar (Glucose & Starch) and Complex carbohydrates (Starch & Fibre) are the two classifications of carbohydrates. Building and repairing tissues, as well as the production of hormones, enzymes, and antibodies, all require proteins. Meat, poultry, fish, eggs, dairy products, legumes, nuts, and seeds are the good source of proteins. Fats serve as concentrated energy sources.

They are necessary for the digestion of fat-soluble vitamins (A, D, E, and K), for insulating and shielding organs, and as a reserve energy source. Macronutrients provide energy, growth of tissue, and their repairing, metabolism, and maintaining cellular structure and function.

Table 9.1: Composition of Nutrients in Fortified Rice Kernels (Hossain, March 2019).

S. No.	Nutrients	Result/100g
1.	Thiamine	0.4 mg
2.	Folic Acid	130 mcg
3.	Cyanocobalamine	1 mcg
4.	Vitamin A	150 mcg
5.	Fe	6 mg
6.	Zn	4 mg

Micronutrients require less from our body as compared to macronutrients. They play a very crucial role in maintaining our health and well-being. Vitamins and Minerals are the two main compositions of micronutrients. Vitamins are organic compounds that are important for metabolism, growth, and overall function of health.

They split into two (Water-soluble vitamins and Fat-soluble vitamins) different groups based on their solubility. Water soluble vitamins include Vitamin C and eight B vitamins (such as B1, B2, B3, B6, Biotin, and Folate). Water-soluble vitamins must be regularly consumed through diet or supplements because the body cannot store them in significant quantities and they are easily excreted in the urine (Gropper, S. S., Smith, J. L., & Carr, T. P. 2017). Fat-soluble include A, D, E, and K vitamins. They play roles in vision, bone health, and blood clotting. The body requires only the smallest quantities of minerals, which are necessary nutrients, for a variety of physiological processes, the activity of enzymes, and overall health.

9.4 Fortification Processes:

Food fortification is the method through which we enhance the nutritional quality of the products by adding some vitamins and minerals to them. It mainly depends upon the selection of very particular and appropriate nutrients for the product. The organized fortification of staple foods, including the iodination of salt or the fluor fortification of toothpaste and tap water, has proven to be particularly successful in dealing with the issue of micronutrient shortage(Susanna Poletti, 2004,). Despite maize's high production potential, maize Fe and Zn contents are lower in its seeds than in other cereals. Therefore, to boost the concentration of Fe and Zn, current biological fortification technologies target the various aleurone cell layers(Susanna Poletti, 2004,).

Initially prevalent nutrient deficiencies are identified through studies and surveys that examine the nutritional status and dietary habits of the target populations.

This is a critical step in identifying the nutrients that are deficient and require food fortification. Appropriate vitamin and mineral forms are chosen for fortification if nutrient deficits are detected.

To prevent iodine deficiency illnesses like cretinism and goitre, for example, iodine is frequently added to salt (a process known as universal salt iodization). To prevent iron deficiency anaemia, iron is frequently added to flour, particularly in areas where diets are deficient in items high in iron (Hurrell, R., & Egli, I. 2010).

Comprehensive quality assurance processes are used throughout the implementation of fortification initiatives to guarantee the efficacy and security of fortified foods. This entails checking the nutrient content of raw materials, keeping an eye on the production process to maintain nutrient levels, and regularly analysing fortified goods to ensure that they comply with regulations.

To figure out how well fortification initiatives are working to reduce shortages of nutrients and enhance population health, ongoing monitoring and assessment are also essential (WHO, 2009). Grain products such as rice, cornmeal, and wheat flour are fortified with folic acid, a synthetic version of folate (vitamin B9), to promote maternal health and reduce the likelihood of neural tube abnormalities in infants (De-Regil et al., 2010).

Campaigns for public awareness are crucial in informing consumers about the benefits of fortified foods and encouraging their acceptance and frequent consumption. Fortification has been accepted as an economical and long-term approach to improve nutrition on a broad scale, encouraging better health and well-being across a variety of populations globally (Food Fortification Initiative, n.d.).

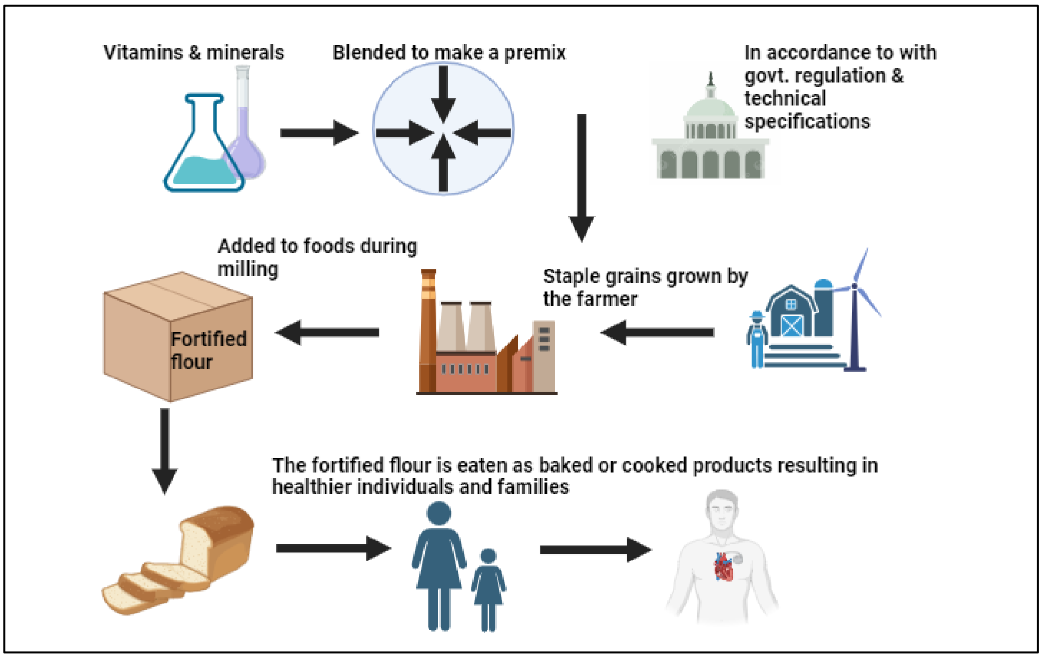

Figure 9.4: Cereal flour fortification (Mannar, M.G.V. & Wesley, Annie. 2016).

The process of including any number of micronutrients in food during processing to raise the number of specific premixes by RDA to replenish nutrients lost during food manufacturing (for example, by washing and milling) is commonly referred to as food fortification(Hossain, March 2019).Besides their increased tolerance to disease and environmental stressors, micronutrient-dense wheat cultivars are especially effective in arid climates and soils lacking trace minerals(Susanna Poletti, 2004,).

9.5 Positive Aspects of Fortification:

There are multiple benefits to fortification, particularly in terms of enhancing public health and changing nutritional deficiencies. Many people can be fed with fortified foods, especially weak ones like young people and pregnant women who may be deficient in certain nutrients.Commonly consumed foods might have particular nutrients added to them to treat specific deficits that are widespread in a community (Horton, S. 2006). Diseases that include rickets (vitamin D deficiency), anaemia (iron deficiency), and goitre (iodine deficiency) can be avoided with the use of fortification.Boosting the intake of vital vitamins and minerals helps strengthen the immune system and lower the rate and level of infections (UNICEF. 2020). As compared to other public health initiatives like direct supplementation programs, fortification is a comparatively inexpensive intervention. One extremely affordable method of addressing the general population's vitamin deficits is food fortification (Hossain, March 2019). In areas where food instability may restrict access to a wide range of foods, fortified foods offer nutrient-dense options. When giving emergency food help, fortified foods can be extremely important since they give impacted populations vital nutrients (Tulchinsky, T. H. (2010). Investigating particular deficiencies in the food and replacing them with vitamins and minerals that are helpful for the population.

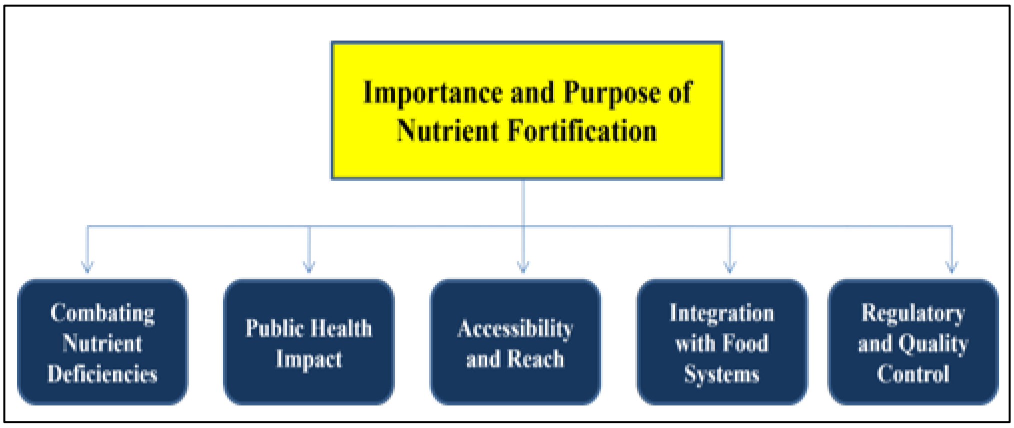

Figure 9 5: Importance and Purpose of Nutrient Fortification

9.6 Negative Aspects of Fortification:

Food fortification has several benefits but also certain disadvantages and difficulties. Some of them are here to understand the disadvantages of fortification. Food products that have been fortified may occasionally lose their original flavour, color, or texture, which will decrease customer approval. Certain nutrients can degrade when processed, stored, or cooked because they are light, heat, and oxygen-sensitive (Zimmermann, M. B., & Hurrell, R. F. 2007). The most vulnerable people might not get fortified foods, especially in isolated or rural locations with limited access to commercially produced foods. This is possible that low-income people cannot buy fortified foods, particularly if they cost more than their non-fortified equivalents (Allen, L. H., de Benoist, B., Dary, O., & Hurrell, R. 2006). Mandatory food fortification raises ethical questions, particularly regarding informed consent and individual choice.

Due to customs and beliefs surrounding diet, fortified foods may be met with resistance in some societies (Hurrell, R. F., & Egli, I. 2010). While fortification can help with certain vitamin shortages, it cannot take the place of a varied, well-balanced diet that consists of a range of entire foods. Relying solely on fortified foods may result in dietary complacency and a decrease in the effort required to eat a variety of nutrient-rich foods (Smith, A. D., Kim, Y. I., & Refsum, H. 2008). Although these challenges, fortification is still an essential public health tactic. It ought to be combined with more comprehensive nutritional interventions, such as instructing individuals about eating a variety of balanced meals and developing customized strategies to fit the unique requirements of various groups.

9.7 Future Directions for Food and Nutrition Fortification:

Taking into account current research and trends, the potential uses of food fortification are extremely diverse. Progress in genomics and biotechnology may provide customized nutrition for fortification based on individual requirements. Crops will naturally become more abundant in some bio-available critical elements through Bio-fortification(Rohner et al. 2023). The stability and absorption of additional nutrients are improved by novel delivery methods such as encapsulation or nano-fortification. Fortification efforts are boosted by public-private collaborations, stronger regulations, and policy backing; rising consumer knowledge drives demand for more fortified products(Olson et al. 2021).

Tailored Nutrition: Future fortification strategies are anticipated to be developed depending on the needs of each individual, which will affect public health, given the genetics and biotechnology advancements in the works.

Bio-fortification: Where access to fortified foods is limited, crops that are naturally bred to contain higher amounts of several important elements that are often supplied during fortification—either via conventional breeding or genetic engineering—may offer viable fortification alternatives.

Advanced Delivery Methods: By improving the stability and bioavailability of additional nutrients, new delivery methods like encapsulation and nano-fortification may increase the efficacy of fortification.

Legislative and Policy Support: To guarantee that many more outreaches are covered by fortification initiatives, it may be helpful to bolster national and international regulations that advocate for mandatory fortification and compliance.

Partnerships between the Public and Business Sectors: By pooling resources from various sectors, both financially and technically, partnerships between the public authority, non-governmental organizations, and the business sector may support extensive fortification initiatives at the national level.

Consumer Education and Demand: By convincing producers to improve the nutritional content of their goods, consumers' growing awareness of the nutritional worth of fortified food can propel market-based fortification.

Technology Integration: Data analytics and new technology will help streamline procedures for population health monitoring, fortification, and the efficiency of fortification programs.

9.8 Conclusions:

Nutrient fortification in food has shown to be a successful tactic in the fight against world malnutrition and promoting public health. This strategy has been extremely helpful in reducing the frequency of nutritional deficiencies, particularly among population groups that are already at risk. It is additionally crucial in preventing diseases that are linked to micronutrient deficiencies World Health Organization. (2021). However, fortification carries disadvantages of its own and is not a stand-alone solution. These include problems that include restricted access to the most vulnerable groups, overconsumption dangers, interactions between nutrients that alter bioavailability, and changes in food's sensory qualities. Administering fortification programs effectively is further complicated by difficulties with cultural acceptance, monetary viability, and regulatory compliance. Considering those challenges, food fortification has several benefits. It is still a reasonably priced intervention that can potentially reach substantial portions of the population with no need for changes in consumer behavior (Allen, L. H., de Benoist, B., Dary, O., & Hurrell, R. 2006). Addressing the technological, legal, and cultural obstacles related to fortification requires ongoing research and international cooperation.

By continuously enhancing fortification methods and adapting them to various demographics, the international community can significantly enhance this crucial public health instrument. As science and technology advance, more accurate fortification techniques are possible, ensuring that a given population receives enough of a given nutrient to be considered essential. Personalized nutrition, for instance, can address specific dietary deficiencies; Bio-fortification can supply nutrient-rich crops in areas where access to foods fortified with various nutrients is limited; and innovative delivery methods, like nano-fortification, can improve the stability and bioavailability of nutrients, thereby increasing the efficacy of fortification. Stronger laws and regulations at all levels will facilitate broad adoption and adherence, and public-private partnerships will provide the resources and know-how for extensive.

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