FOOD FORTIFICATION
Global Agribusiness

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Nutrient requirements are frequently not met due to the limited availability and affordability of an adequately diverse diet that includes plant- and animal-source foods. **Food fortification refers to the addition of one or more nutrients to a food, during or after processing**. The industrial fortification of foods started almost 100 years ago to address diseases/disorders of public health concern resulting from inadequate intake of specific micronutrients from the population's food base. Due to these early successes, fortification continues to be an important strategy to ensure the required intake of nutrients where they are not adequately supplied by the normal diet.

Brief History of Food Fortification

The concept of adding a product to a food/beverage to affect a biological function was first recorded in 400 B.C. by the Persian physician, Melanpus, who suggested to add iron filings to wine to increase soldiers' "potency."

In the early 20th century, the industrial fortification of widely-consumed foods developed as a strategy to prevent and reduce the prevalence of specific nutritional deficiencies of public health importance in non-emergency as well as emergency contexts; these initiatives emerged thanks to major discoveries in nutrition science, and advances in the synthesis and mass production of key vitamins and minerals.

In 1923, Switzerland was the first country to fortify salt with iodine to eliminate goiter, followed by the United States in 1924. With industrial-scale synthesis of several vitamin and mineral compounds in the 1930s and 1940s, wide-scale fortification of foods to address the high public health burden of micronutrient deficiencies became technically and economically feasible. During that period, vitamin A fortification of milk and margarine was implemented in Denmark, UK and the United States, where fortification of white flour and bread with vitamins B1, B2 and B3, as well as iron, became mandatory in 1943. Around this time, the beneficial impact of flour fortification in Newfoundland led to mandatory fortification of wheat flour in Canada as a whole.

In the 1950s and 1960s, food fortification was initiated in many Latin American countries, including salt iodization and fortification of wheat flour, margarine and milk. Chile was particularly successful in eliminating the public health burden of pediatric iron deficiency anemia through fortification of commercially produced foods for infants and toddlers starting in the early 1970s, and that of neural tube birth defects (NTDs) through the addition of folic acid to wheat flour in the early 2000s. Mandatory fortification of wheat flour was introduced in many countries of the Middle East and North Africa in the 1990s, and Oman became the first country in the world to effectively fortify wheat flour with folic acid in 1996. Many countries across sub-Saharan Africa, Asia, and the Pacific initiated fortification of staple foods (e.g., wheat and maize flour, pasta, rice and vegetable oil) and widely consumed condiments (e.g. fish sauce, soy sauce and bouillon cubes) since the early 2000s.

Global Burden of Micronutrient Deficiencies

Despite substantial progress during the past century, it is still estimated that close to two billion people, including in industrialized countries, suffer from vitamin and/or mineral (or micronutrient) deficiencies.

Although the physical and medical consequences of severe forms of micronutrient deficiencies have been known for over a century, the even larger negative societal consequences of such deficiencies on physical growth, cognitive development and economic development of nations has only been documented within the last few decades.

Brief History of Food Fortification (Cont…)

Large-scale fortification of widely consumed staple foods and condiments continues to be an important component of the food value chain and, according to the Copenhagen Consensus* (an international grouping of Nobel Laureates who have undertaken economic analyses of various global problems and their available solutions), its estimated cost-benefit ratio to society is close to 1:30. As a result of successes in the elimination of key deficiencies as problems of public health significance and the strong evidence base supporting it, micronutrient fortification of key staple foods and condiments is today mandated in many countries and jurisdictions around the world.

Besides large-scale food fortification, the health sector operating in humanitarian and emergency contexts has also used fortified foods in targeted ways to address and prevent nutritional problems among specific at-risk populations, such as infants and young children, mothers and women of reproductive age, and the elderly as well as people living with chronic diseases or in situations of acute nutritional deficit.

In more recent decades, with advances in food science and technology, food fortification has become adopted by the processed food and beverage industry as a commercial strategy to target increasingly health-conscious consumers, particularly in developed economies. Whereas large-scale food fortification for public health purposes aims to achieve maximum population reach, commercially-driven fortification usually targets higher-value niche markets, employing nutrition science to support product differentiation and marketing.

Types of Food Fortification

Typically, food fortification is performed to:

- Restore nutrients lost during food processing to a level approximately equal to the food's natural content; this is also referred to as enrichment.
- Add nutrients that may not be present in, or contained at a lower level, naturally in the food; this is typically referred to as fortification.
- Standardize the nutrient content present in variable concentrations in a food product, e.g. the addition of vitamin C to orange juice to standardize the concentration of the vitamin to compensate for changes due to seasonal and processing variations.

Public-Private Sector Partnership

Food fortification is, by its nature, a public-private partnership because it cannot be achieved without the involvement of the different stakeholders. The government plays an important role in setting standards, policies and regulations, health considerations and public health budgets; various ministries need to be engaged and involved, including ministries of health, agriculture, trade and industry, social welfare, planning and finance.

The private sector complements this role by advancing innovation to fortify staple foods, condiments and other foods commonly consumed by the population; NGOs contribute through their role as advocates and social aggregators; and academia through research and advances in fortification expertise and technology. Donor funds also play an important, catalytic role in stimulating investments in nutrition improvement before commercial sustainability can be achieved.

*The Copenhagen Consensus: http://www.copenhagenconsensus.com

KEY CONSIDERATIONS ON FOOD FORTIFICATION

Conducive Environment

Basic requirements for production of safe, nutritionally beneficial, and commercially sustainable food fortification include:

- Reliable data on average daily per capita consumption of the target food in the country.
- Development of, and compliance with, national technical standards for fortification of the food product, especially the added concentration (based on the per capita consumption) and formulation of bioavailable forms of fortificant nutrients (e.g., atomized and hydrogen-reduced forms of iron fortificant are deemed non-bioavailable).
- Technical capacity and implementation of internal Quality Assurance and Quality Control (QA/QC) processes by producers of fortified food to consistently ensure marketing of safe and adequately fortified food.
- Technical and human capacity of government to ensure systematic monitoring and enforcement of fortified food standards, especially at production sites and points of import.
- Promotion and social marketing to encourage populations to regularly consume fortified foods in place of non-fortified products.
- Ongoing public health surveillance to document anticipated improvements in micronutrient status of target populations (who consume fortified foods) over time.

Mandatory vs. Voluntary Fortification

As an effective public health intervention, adequately fortified food(s) must be regularly consumed by the majority (>80%) of the population(s) in a defined geographic area. Global experience has shown that mandatory fortification of widely consumed food products with appropriate levels of added nutrients can sustainably result in the improved nutrient status of populations. Some industry-initiated voluntary fortification of staple foods, beverages or condiments as a marketing approach have been commercially sustained in economically well-developed countries, where consumers can afford the slightly higher price of a fortified food compared to its non-fortified variant (e.g. fortified vs. non-fortified milk). Similarly, marketing of “niche” products, e.g. fortified sports drinks and bottled water marketed to “physically active” consumers, has been commercially successful in high-income societies and likely impact the nutritional status of the relatively small proportion of consumers who regularly consume those products.

National fortification regulations and standards, where they exist, supersede global recommendations as they are informed by in-country public health evidence. This is why global recommendations are usually provided as ranges that can accommodate the potential in-country circumstances. Nonetheless, differences in standards between countries can lead to potential issues when ingredients, such as premixes, need to be shipped across national borders.

Economic Considerations

As highlighted above, multiple actors across different sectors must be engaged to ensure food fortification can be done successfully at the scale needed to have an impact on a public health problem. While the 1:30 cost-benefit ratio of food fortification interventions declared by the Copenhagen Consensus makes for compelling advocacy for governments to adopt the approach as a complement to other nutrition improvement strategies, it is imperative to fully understand the costs involved in food fortification across its value chain, and which stakeholders must bear which costs. Besides obvious considerations such as i) the capital investment needed for fortification facilities and/or equipment, and ii) the recurrent cost of the fortificant premix, other costs may include iii) any related import tariffs (where relevant), iv) implementation of new processes in the production line and associated training and/or manpower requirements, and v) internal and external quality assurance and quality control (QA/QC) facilities and implementation across the value chain. For industry, perhaps the most important outcome of investing in food fortification for public health purposes is achieving market returns that would, at the very least, be comparable to a business-as-usual scenario; where this is not the case, other stakeholders may need to step up to share some of the risk and potentially help to bridge this gap.

Safety of Fortified Foods

- **Risk of overdose:**
  To date, there has been no documented evidence of toxicity of vitamins or minerals in populations that regularly consume fortified foods produced according to official standards. Furthermore, there is no evidence that fortification of a food product leads to people eating more of that food compared to the average amounts they consumed of it before fortification. For example, salt iodization or wheat flour fortification have not resulted in people eating more salt or bread.
- **Evidence of under-fortification:**
  Marketing of fortified foods containing less than the required levels of added nutrients has been documented, mostly in developing countries. This is often due to poorly implemented QA/QC procedures during production. However, there are also examples of producers who under-fortify products to gain financial advantage over market competitors. Once identified, consumers should be informed of such mislabeled product brands by the appropriate enforcement and health authorities, and the producers prosecuted accordingly.
- **Contamination:**
  Fortified and non-fortified foods may become contaminated with environmental, chemical and biological hazards at various points in the chain from “the farm to the fork.” At the fortified food production facility, adherence to adequate QA/QC procedures and protocols, starting from the point of delivery of the raw materials through the product processing chain, reduce the risk of product contamination. Product handling procedures, storage conditions, packing processes, etc. must be implemented with appropriate sanitation and hygiene practices to avoid hazardous contamination of fortified foods. A particular hazard -- albeit, not directly linked to the process of fortifying foods -- is the growth of dangerous aflatoxin-producing molds due to moist and hot product storage conditions at production sites, as well as during transit to markets, and at the market level. Storage and transportation of foods in cool and dry conditions, away from long exposure to direct sunlight minimizes risk of aflatoxin contamination.

Consumer Acceptance & Regulatory Standards

Existing guidelines on food fortification generally provide guidance for optimal product outcomes. It is important to follow these guidelines to avoid sensory/organoleptic issues as some fortificants may change the color, taste and texture of the food vehicles. Specifically, fortification with iron, calcium, vitamin A and riboflavin can be problematic for the food industry, which is sensitive to the risk of losing market share due to such issues. Research and development into different forms of these fortificants have evolved to address these. More specific detail on sensory/organoleptic issues related to specific food vehicles and fortificants will be presented in Leaflet 12 (Best Practices), as well as current strategies and solutions to address them.

Fortified foods are considered “credence goods” because consumers cannot readily evaluate their quality with regard to the fortificant content compared to non-fortified versions. Thus, consumers depend on the fortified food producers, importers and retailers, as well as the regulatory monitoring and enforcement agencies to ensure that a fortified food contains the required and publicized amounts of added nutrients.

In summary, production and marketing of safe and adequately fortified foods require the use of appropriate technologies and strict adherence to internal QA/QC procedures based on international guidelines and standards (e.g. GMP, HACCP, etc.), including needed documentation at all steps in the production chain.

Consumer Information & Social Marketing

Encouraging consumers to accept fortified foods as a “normal” part of the diet, especially when such foods are marketed for the first time, must be done deliberately. The promotion and social marketing approach should be based on appropriate formative research related to local knowledge, attitudes and beliefs to avoid misunderstandings and ill-founded rumors that could lead to non-acceptance of the product(s). It is also essential to consider targeting influencers of attitudes and practices of appropriate target audiences; for example, in some societies, elderly members of the family or adult male members influence the food purchasing choices of the adult females, who are responsible for purchasing grocery items. In contrast, in other societies, adult males may be responsible for grocery shopping even if females do most of the cooking at home. Thus, promotion channels should consider the influence of household dynamics on food purchasing decisions.

Certain products, such as condiments (sugar, salt) and what would be considered highly-processed foods, are generally recommended to be consumed in limited amounts. WHO specifically recommends limits to sugar and salt consumption as part of a healthy diet, and those limits apply whether they are fortified or not. Nonetheless, sugar and salt, and foods containing them, including processed and ready-to-eat foods, are often widely and regularly consumed in any given country and are therefore usually suitable vehicles for mass fortification. While there may be concerns that fortifying these products may send a signal to consumers that it is all right to consume them in excess of recommended limits, this is never – and should never be – a goal of any social marketing or promotion of fortified condiments. Rather, the goal should be the 1:1 replacement of non-fortified products with the fortified versions. In countries with mandatory fortification of salt and/or sugar, processed or ready-to-eat food products that are manufactured with fortified salt or sugar are indirectly fortified as well.

Food Fortification

CHECKLIST TO ASSESS FOOD FORTIFICATION POTENTIAL

This checklist will guide the assessment on the potential to successfully fortify which food vehicle, with which fortificants and for what purpose (public health or economic benefits). The specific technical considerations are described in the Best Practice section/leaflet. This checklist is a product of the authors' decades of experience in the field of food fortification (across academic/scientific, operational, industrial and political/policy domains), and represents the core questions and issues important to food fortification. Additional questions based on local circumstances and the specifics of IFC clients' resources, capabilities, supply chains, end markets and other issues of relevance need to be further considered.

Country Situation

Nutrition/Diet/Health

a. Are there micronutrient deficiencies of public health concern?
   - If yes, which ones?
   - Which population group(s) is/are affected?

b. What official documents record the micronutrient deficiencies?
   - National health and nutrition survey?
   - Assessments by international NGOs, UN agencies?

c. What is the main staple or main food people eat?
   - Is this food eaten throughout the country and by everyone?
   - Are consumption surveys/data available?
   - Are there national tables on the nutrient content of local food?
   - What is the traditional diet eaten daily?

d. What is/are the main disease(s) in the country?
   - Which population group(s) is/are affected?

National Programs/Initiatives/Policy

a. Is there a national nutrition policy?
   - If yes, are fortified foods part of the nutrition strategy?

b. Are there initiatives to improve dietary quality run by local and international NGOs and/or UN agencies?
   - If yes, which ones?

c. Is the private sector involved in nutrition initiatives?
   - If yes, which companies?
   - Under SUN?
   - What are the key partnerships that exist?

d. Are there laws for mandatory fortification of major staple food(s)?

Consumer

a. Is there a consumer association/network in the country? If yes, are fortified foods part of the knowledge?

Technical Fortification Issues

1. What type of food is fortified? Oil, porridge, biscuits, etc.?
2. What is the distribution/retail system of the food?
3. How will the food reach the end consumer? Through wet markets, supermarkets, etc.?
4. Where are the raw materials of the processed foods sourced from? Locally, imported?

Private Sector (IFC clients)

1. What food product(s) is/are produced by the company?
2. Does the company meet production criteria/regulations, including third-party certification, and food safety management and QA/QC systems in place?
3. Where are the raw materials sourced from? Locally available or imported?
4. Is this product distributed throughout the country?
5. Who eats the product? Is it consumed in a manner consistent with the fortification method?
6. What is the product's market share? What is the potential impact of fortified product to market share?
7. Is the product exported to other countries?
8. Does the company enjoy specific government subsidies or tariff benefits?
9. Is the company engaged in partnerships and/or SUN business activities?

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Context

Vegetable oil is an ideal vehicle for vitamin A and D fortification due to its high lipid content, high consumption, broad distribution, and existing centralized processing and delivery systems required for fortification and sustainability. Types of commonly available vegetable oils include palm oil, soybean oil, rapeseed oil and sunflower oil, and they have different physical properties and fatty acid profiles. In reality, vegetable oils are rarely pure, and are often blended together to obtain desirable textural, oxidative and nutritional properties. Thus, the term 'vegetable oil' is used here in reference to a blend of different plant-based oils. The impact of vitamin A fortification in food has been well understood from studies dating back to the 1950s. Mandatory vegetable oil fortification legislation was first introduced in 1965 in Pakistan. Currently, 30 countries mandate the fortification of vegetable oil with vitamin A. Voluntary fortification of vegetable oils is carried out in 13 countries. Generally, vegetable oils are fortified with vitamin A but may [also] be fortified with vitamin D in some countries.

Hydrogenation converts liquid vegetable oils into solid fats, such as margarine. Even though the vitamin A and D content in margarine is negligible, fortification with these vitamins can make margarine an important source of these nutrients, as well as a source of energy.

Vitamin A is commonly found in eggs, whole milk and meat as retinol, the active form of vitamin A, and in spinach, pumpkin, papayas, mangoes and carrots as β-carotene, the precursor of retinol. However, poor quality diets have led to widespread vitamin A deficiency (VAD) in many developing countries, impacting as many as 130 million children under 5 years of age and 7 million pregnant women. VAD causes poor vision and blindness, increased susceptibility to infections, as well as increased likelihood of morbidity and mortality. Although fatty fish (e.g. tuna, mackerel and salmon), liver and eggs are sources rich in cholecalciferol (vitamin D3), humans can naturally produce vitamin D3 in their skin upon ultraviolet (UV) light exposure. Ergocalciferol (vitamin D2) are present in certain nuts, mushrooms and plants in negligible amounts. Approximately 1 billion people worldwide suffer from vitamin D deficiency (VDD) or insufficiency, a condition that is determined by factors such as low exposure to sunlight, excessive clothing (minimizing skin exposure to sunlight), dark skin pigmentation, cloudy or winter seasons and poor diet quality or diversity. Infants, teenagers, pregnant women and the elderly are especially vulnerable to VDD, and have greater risks of rickets, osteomalacia, osteoporosis and muscle weakness.

Fortificants

Vitamin A and Vitamin D

Forms

- Fat-soluble vitamins A and D are oils in their natural state. They are readily soluble and dispersible in oil matrices, allowing for uniform distribution.
- Vitamin A: Vegetable oil fortification with vitamin A is generally done with retinyl palmitate and acetate. While β-carotene, a provitamin A carotenoid, is naturally present in softly refined crude palm oil, which may be consumed in certain populations, β-carotene exhibits extremely poor stability when the oil is used for frying. The degradation of trans-β-carotene into 13-cis- and 9-cis-β-carotene results not only in undesirable oil color change (from red to dark grey and black, respectively) but also the release of dangerous free radicals.
- Vitamin A palmitate or retinyl palmitate (1.7 million IU/g) is the most widely-used fortificant globally.
- Vitamin D: Liquid vitamins D2 and D3 in an oil form are available for vegetable oil fortification.

Given the importance of fortified vegetable oil for public health, a discussion of some issues around stability, retention and bioavailability of micronutrients is warranted:

General

- Vitamins A and D share certain properties, including fat solubility, light sensitivity, moisture, oxidation and (to a certain extent) thermal stability.
- Vitamin E, in the form of alpha-tocopherol, is more often added as a technical antioxidant than as a nutrient as it prevents rancidity and prevents oxidation.
- Storage time has a negative impact on vitamin A and D retention. However, the shelf-life of fortified vegetable oil can be maximized if kept in under appropriate storage conditions.
- The peroxide value (PV) of fortified oil increases with cooking time and light exposure. Vitamin A and D retention decreases with increasing PV as the vitamins will oxidize faster and lose their activity when present in highly oxidized vegetable oils.
- Fortification standards often do not consider the potential effect of poor quality vegetable oils on vitamin A and D stability.

Vitamin A

- Vegetable oil is a suitable vehicle for vitamin A fortification as the lipidic matrix protects against vitamin A oxidation, improving vitamin A stability and retention during storage and cooking. It also allows for good bioavailability in humans.
- Retinyl palmitate has great overall stability with a variety of food preparation techniques. While frying fortified oil results in some loss of vitamin A content, the retention rate of retinyl palmitate is still acceptable for delivering vitamin A to deficient populations. Repeated frying of the same fortified oil at high temperatures will result in progressive loss and over 60 percent destruction of vitamin A. This varies between food preparation techniques and type of food being fried.
- Cooking in the open air at high temperatures and for a longer time is more damaging towards vitamin A in fortified oils. In comparison with shallow frying, deep frying destruction of added vitamin A is more pronounced.
- Vitamin A-fortified vegetable oil is stable when stored at room temperature in sealed containers and protected from light.
- Vitamin A fortificant has relatively good bulk stability at room temperature, and exhibits greater retention characteristics at 5°C.
- Fluorescent lights commonly used in retail displays and households can result in more than 80 percent vitamin A loss in fortified vegetable oil.
- The oxidation of vegetable oils exerts a large negative impact on vitamin A retention, while storage time and light exposure have a less or similar influence on vitamin A retention.

Vitamin D

- Little is known about the bioavailability and stability of vitamin D in vegetable oil. Studies have shown that vitamin D3 has good bioavailability in fortified foods such as milk, cheese, yoghurt, bread and orange juice.
- Most refined vegetable oils have low specific heat and high smoke points (>180°C), and are a better choice for frying foods. Thermal transformation of vitamin D3 may occur between 110°C to 170 °C, with an inverse relationship between temperature and time of cooking. While vitamin D is relatively heat-stable during cooking, high loss of vitamin D has been reported when fortified vegetable oils are used for frying. As such, vegetable oils may not be a suitable food vehicle for vitamin D fortification.
- Storage time, light exposure and high oxidative status of vegetable oil (i.e. high PV and acid value) have a negative impact on vitamin D3 retention. Unlike with vitamin A, the stability of vitamin D-fortified vegetable oils is not extensively researched.

Recommended Levels

- The World Food Program (WFP) recommends fortifying vegetable oils with 30,000 IU vitamin A/kg and 3,000 IU vitamin D/kg.
- An overage is typically added to account for losses of vitamin A during handling, storage and cooking. Optimizing the amount of this overage by improving handling, storage and cooking methods can result in considerable savings for industry and government while guaranteeing a supply of adequately fortified oil to consumers.

Special Considerations

- The issues surrounding oil fortification is centered around the use of poor quality vegetable oils. High peroxide values (PV) and acid values of vegetable oils are detrimental to its quality and shelf life, causing them to quickly become unfit for human consumption. Rancid vegetable oils at production level contain great amounts of degradation products, such as free fatty acids and peroxides. Peroxides are later broken down into reactive oxygen species and other free radicals, which eventually become carcinogens when consumed, increasing the risk of cancer and other chronic diseases. Furthermore, high PV and acid values cause accelerated losses of vitamins A and D in fortified vegetable oil.
- Soybean oil and sunflower oil are high in polyunsaturated fatty acids, which makes them more prone to oxidative cleavage and accumulating more peroxide at any temperature.
- There have been concerns that the fortification of vegetable oil and its promotion may lead to an increase in its consumption and contribute to increasing obesity rates. However, it should be clarified that any promotion of fortified vegetable oil would aim to shift consumption from non-fortified oil to fortified oil, and not to stimulate increased consumption.

Technical Specifics

- PV and acid values are used as a proxy of vegetable oil quality. PV expresses the degree of fat oxidation. WFP specifies that PV and acid values should be below 2 mEq/kg and 0.6 mg KOH/g, respectively; this is considered optimal. The initial PV of vegetable oil during production should be as low as possible to ensure that the vegetable oil does not exceed the PV standard of 10 mEq/kg at the time of consumption.
- Sub-optimal refining processes, particularly deodorization, can result in high PVs of vegetable oils.
- Smoke point is the temperature at which fats in the vegetable oil break down to form glycerol and free fatty acid. When heated beyond the smoke point, vegetable oil produces toxic fumes, free radicals and carcinogens, simultaneously destroying beneficial nutrients and phytochemicals present in unrefined vegetable oils. Refining a vegetable oil removes impurities and free fatty acids, thereby increasing its smoke point.

Equipment

- Vegetable oil fortification typically does not require special equipment.
- For continuous production: An adapted automatic feeder with a flow rate-control device can be used to regulate (by weight or volume) the addition of the fortificant into the vegetable oil product line according to the product flow. The feeder tank containing the fortificant is usually equipped with electrical/electronic safeguards to halt the product line in case the (1) flow of fortificant is insufficient or excessive, or (2) product flow is inadequate to allow uniform mixing.
- Vitamin A and D fortificants (in oil form) can be blended with vegetable oil either continuously using static mixers or in batches using batch mixers. A homogenized end-product is achieved after stirring for a specific length of time.
- Alternatively, a rotary mixer can be used for continuous or batch fortification.

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Context

Cereals are an important source of carbohydrates, protein and essential micronutrients. The most important cultivated cereal crops are wheat, maize and rice. The WHO recommends the fortification of wheat and maize flour (with iron, zinc, folic acid and vitamin B12 at a minimum) as part of national nutrition strategies to address micronutrient malnutrition. Recommended levels are based on evidence of health impact and, according to the Food Fortification Initiative (FFI), 87 countries have at least one cereal mandatory staple flour fortification (as of January 2018). The vitamins and minerals used for flour fortification are typically prescribed by the government of the country based on the evidence of micronutrient malnutrition.

Fortification of cereal grain flours further means that food products using these fortified flours as ingredients are fortified, such as breads, biscuits, noodles, etc. This applies particularly where fortification of flour (i.e. wheat, maize and/or, in some cases, rice) is mandatory.

Rice kernel fortification has been gaining momentum and WHO is set to issue guidelines for fortified rice in Q2 2018. The World Food Programme (WFP) has already set technical specifications for fortified rice as part of its food assistance and development assistance program.

WHEAT FLOUR & MAIZE FLOUR

To be fit for human consumption, wheat is processed into flours in mills. Wheat flour is used to make bread, biscuits, pasta, and other products. With its widespread geographic distribution, acceptance, stability, and versatility, wheat flour is a suitable vehicle for mass fortification.

The processing and consumption of maize varies greatly around the world. Two of the most popular products are maize flour and maize meal. To produce maize flour, the germ and outer layers of the maize grain are removed, and the endosperm is milled; in contrast, the whole grain is ground into a granulated meal in a range of particle sizes (coarse to fine) to produce maize meal. As with other grains, removing the outer layers of the maize kernel in the milling process leads to the loss of most of its natural content of vitamins and minerals. Like wheat flour, however, the scale of its consumption particularly in large developing nations makes it another ideal vehicle for food fortification.

Whole grain flours retain a significant proportion of the intrinsic nutritional value of the whole grain. However, the consumer preference is to consume food made with flours which have had the bran and germ portion of the kernel removed. This results in a loss of essential vitamins and minerals which can then result in micronutrient deficiencies, particularly of iron, zinc, folic acid and B group vitamins. These deficiencies can result in increased levels of anemia, neural tube birth defects and other related diseases in populations where processed flours are the main energy source in the local diet.

Fortificants

Vitamin A, thiamine (vitamin B1), riboflavin (vitamin B2), niacin (vitamin B3), folic acid (vitamin B9), vitamin B12, vitamin D, iron and zinc.

Special Considerations

- In industrialized countries, the milling industry structure is made up of large-scale mills with rated grinding capacities of 50 MT of wheat or maize per day (24 hours). In less developed countries, there are mills that have capacities of 20–50 MT per day. These are considered medium-scale mills.
- Both large-scale and medium-scale mills can fortify flour using feeders. In addition, these mills are registered businesses with government agencies, such as the ministry of trade, ministry of finance, ministry of taxation and local municipal governments.
- However, in many countries, particularly in Africa and South Asia, there is an informal milling structure made up of small hammer mills or chakki mills (South Asia). While, technically, these mills can fortify using simple technologies, realistically, small mills would struggle to implement the necessary QA/QC processes to ensure the quality of fortification, whereas medium to large mills would be better resourced to do so.

Technical Specifics

- Vitamins are sensitive to heat, oxidizing and reducing agents, light, and other kinds of physical and chemical stress; therefore, they are less stable than minerals when used to fortify foods. Vitamin A, D, and folic acid are unstable when exposed to air, light, and heat. Vitamin B1 is sensitive to heat and alkalis. Vitamin B2 is sensitive to light and alkaline pH. Vitamin B6 and biotin are pH-sensitive. Niacin is the most stable vitamin being essentially unaffected by light, heat, or pH.
- While vitamins are generally stable in flour, vitamin A is adversely affected by high humidity and temperatures. Using encapsulated forms of vitamin A can help to overcome this problem.
- Vitamin losses in fortified flour occur mostly during baking, a common process wheat flour products undergo. Nonetheless, over 70% of vitamin fortificants remains intact as the temperature inside the baked product is much lower than that outside. In cooked pastas, this proportion is between 65-85%of vitamins.
- Losses in micronutrient content can be overcome through overages (the inclusion of an additional amount calculated to compensate for any losses).
- Quality control standards for both commercial premixes and fortified flour should be established. Among the methods for determining the micronutrient content of fortified flour are fluorometric (for B1 and B2) and spectrophotometric testing (for iron), and testing methods using more sophisticated equipment (HPLC for vitamin A, folic acid, and niacin; atomic absorption for iron).

Equipment

Flour fortification is carried out by adding a premix of vitamins and minerals to the flour as the flour is being produced. The premix will include filler, free flow agent to ensure consistent addition to the flour. Large-scale flour mills (rated capacity of 20 MT per day and above) require the use of a feeder to deliver the premix. The feeders use three types of discharge mechanisms, roller, disc and screw. Modern feeders can be equipped with load cells which allows for the automatic weight measurement of premix going into the flour stream.

RICE

Unlike wheat, rice is predominantly consumed in its original grain form. Nonetheless, rice is also milled to remove the outer husk from the grain to produce polished white rice kernels, the preferred appearance for consumption in most countries where it is the main staple. Iron, zinc, calcium, thiamine, riboflavin and niacin are naturally found in rice but levels depend on the type of rice. As these nutrients are largely in the outer layers of the grain, 75 percent to 90 percent of them are lost after milling.

To fortify rice, three distinct methods have been used, of which only two qualify for impactful fortification, meaning that the nutrients are stable under different cooking and storage methods. These two methods are: rinse-resistant coating and extrusion.

- Coating: Rice is sprayed with a mix of vitamins and minerals plus ingredients such as waxes and gums so that the nutrients adhere to the rice. Then the rinse-resistant coated rice kernels are blended into non-fortified rice kernels at ratios between 1:50 and 1:200.
- Extrusion: The extrusion methodology allows to use broken rice (inferior in appearance and cheaper than full body grains) and to transform the broken rice into rice flour to which then a powdery mix of vitamin and minerals are added. This dough (consisting of between 91 percent to 99 percent rice flour and the rest, the vitamin and mineral premix) is then transformed into rice kernels that have the shape, color, taste and are cooked as natural rice kernels. The fortified kernels are similar to unfortified rice in size, shape and density and little segregation occurs during transport and storage of blended, fortified rice kernels.
- Dusting, the third method (used mainly in the USA), is not recommended as the rice kernels are only dusted with a powdery mix of vitamins and minerals, which is easily washed away when the rice is rinsed or if it is cooked in excess water that is discarded.

The use of fortified rice kernels is now accepted to be the most effective way of ensuring that the added micronutrients will be consumed by the population. Rice (kernel) fortification is currently mandatory in six countries, including Costa Rica, Nicaragua, Panama, Papua New Guinea, Philippines and the United States (four states only), and many initiatives are underway, mainly market-led in voluntary fortification settings.

Rice fortification may be a relatively new public health intervention; nonetheless, it builds on learnings from the long experience of fortifying wheat flour and is a promising approach for reducing micronutrient deficiencies in many developing countries.

Rice is also milled into rice flour for use in processed foods such as noodles, crackers, biscuits – essentially, it can be used in the same way as wheat or maize flour. The fortification of rice flour is the same as for wheat flour.

Fortificants

WFP recommends the following fortificants: Vitamin A, vitamin B1 (thiamine), B3 (niacin), B6 (pyridoxine), vitamin B9 (folic acid), vitamin B12 (cobalamin), vitamin D, iron, zinc.

Special Considerations

- As with wheat, there are many small rice mills that prepare the rice kernels into white polished rice kernels or produce rice flour. Centralized processing is recommended to allow proper QA/QC measures to be put in place.
- Since the fortification of rice kernels requires specific technology, only economically stronger players will be able to either produce the fortified kernels or order them for blending into non-fortified rice kernels.
- Government safety nets programs can be helpful to create an up-take market for fortified rice while the private sector positions fortified rice in the market.
- Fortified rice flour is an option and follows the same mechanism as wheat flour fortification. However, it has a smaller share of consumption and hence, is not a major vehicle for fortification for public health purposes.

Technical Specifics

- The level of the fortificant depends on the level of rice consumption; for example, low rice consumption (below 75 g/day), medium (below 75-149 g/day), high (150-300 g/day) and highest (above 300 g/day). Therefore, the level of the fortificants will be higher in the low consumption range than in the high consumption levels.
- Technically, most vitamins and minerals can be added to extruded rice kernels. However, vitamin C adds a brown color, beta-carotene, bright orange color, and vitamin B2, a pinkish hue, to the kernels.
- WHO guidelines for rice fortification were released in May 2018.

Equipment

The equipment that is used for fortifying rice flour is similar to that of wheat flour where the premix is dosed into the flour via a micro-doser during the milling process.

To produce fortified rice kernels, two specific types of equipment are needed: one is to produce the fortified rice kernel – this is an extruder machine for either hot, warm or cold extrusion; or coating equipment to produce rinse-resistant fortified rice kernels. The second equipment is a blender that blends in a systematic way the fortified rice kernels into non-fortified rice kernels.

Food Fortification

PACKAGED AND PROCESSED FOODS SECTOR

IFC International Finance Corporation WORLD BANK GROUP

Creating Markets, Creating Opportunities

Context

This sector comprises a wide range of different food types. Among those some have been used for fortification for decades like salt or sugar. The fortification of fish sauce, soy sauce and bouillon cubes however is a more recent approach to combat micronutrient deficiencies. Other common packaged/processed products (e.g. bread, noodles, margarine) are indirectly fortified by using fortified ingredients like cereal flour and vegetable oil (see Leaflets 3 and 4).

Condiments in general are consumed worldwide; nonetheless, there are those that are region-specific, such as fish sauce in Southeast Asia and South China. Generally, they are used for adding flavor to foods or to enhance their taste and represent a huge potential for enriching low-diversity, nutrient-poor diets with micronutrients. Delivery channels for condiments already exist, even reaching remote areas. This makes condiments very suitable vehicles for micronutrient fortification. Various definitions exist for this food group, with different scopes of included items. Here, fish sauce, soy sauce and bouillon cubes are included, as well as salt and sugar as those are mainly fortified for public health purposes.

Despite the suitability of these condiments for mass fortification efforts, it should be kept in mind that WHO recommends limits to the consumption of both sugar and salt as part of a healthy diet, whether they are fortified or not. There are concerns that fortifying these condiments may send a signal to consumers that it is all right to consume these products (or processed products that contain them) in excess of the recommended limits. However, this should never be (and generally is not) the goal of any social marketing or promotion of fortified condiments; rather, the goal should be the 1:1 replacement of non-fortified condiments with the fortified versions. In countries with mandatory fortification of salt and/or sugar, processed or ready-to-eat food products that are manufactured with these products are indirectly fortified as well.

Besides condiments, other types of processed food that are fortified include those made using fortified ingredients, such as cereal grain flours (i.e. wheat, maize, rice), e.g. breads, biscuits, noodles. This applies particularly where fortification of any of the above-mentioned flours is mandatory.

Margarine is a final category of product included in this leaflet. Although it is made mainly from vegetable oils, the fortification of margarine requires the addition of the fortificant premix during production.

SUGAR

Sugar has been used as vehicle for mass fortification since the 1970s, when Guatemala started fortifying sugar with vitamin A to combat the widespread problem of vitamin A deficiency. The effectiveness of the program and the biological efficacy had been proven early on: vitamin A status among preschool-age children improved and vitamin A concentration in the breast milk of lactating women increased. This success encouraged other countries to initiate sugar fortification programs. Nonetheless, sugar is fortified in only a limited number of countries, mainly in Latin America and sub-Saharan Africa, and its use in global public health efforts is accordingly limited. Sugar fortification with other micronutrients, like iron, iodine and folic acid, is also possible, but has been implemented for voluntary rather than public health purposes. Sugar is a suitable vehicle for mass fortification in sugar-producing areas because it is widely and regularly consumed, usually relatively soon after production and purchase; and because the sugar processing industry is highly centralized and consolidated, and the fortification process is relatively easy and economically feasible. Nonetheless, strong commitment and involvement in program planning by the sugar industry are critical to program success and sustainability.

Fortificants

Vitamin A, mainly (iodine, folic acid, iron – possible but limited application, to date)

Forms

- Vitamin A: Usually, dry and water-soluble forms of retinyl palmitate with fair stability are used. Vitamin A is highly sensitive to light, oxidizing agents, heat, and acids, and hardly sensitive to reducing agents, humidity and alkalis. The level of fortificant needs to be carefully calculated based on per capita sugar consumption and the size of the vitamin A intake gap in the population. Sugar consumption of the target group should be large enough, at least 15 g/day (5.5 kg/year). In general, it is advised that the amount of vitamin A supplied through fortification meets at least 15% the RDIs for the target group. Adequate overage has to be added to compensate for losses during processing, distribution and storage. The recurrent cost of the vitamin A fortificant would be the most significant expense in sugar fortification.
- Iodine: Fortification of sugar with iodine alone or double-fortified with vitamin A is possible.
- Folic acid: Double fortification of sugar with vitamin A and folic acid is possible. For stability reasons, an encapsulated premix should be used to keep the active ingredients physically separated.
- Iron: Double fortification of sugar with vitamin A and iron is possible. However, not all iron compounds are suitable, e.g. NaFeEDTA-fortified sugar causes color change when added to tea or coffee. Iron tris-amino chelate (FeAAC) shows high iron bioavailability, and it does not change the organoleptic characteristics of the sugar nor the color of products to which the fortified sugar is added.

Technical Specifics

- Fortified sugar should be packed in containers that protect it from direct sunlight and excess humidity. Appropriate packaging needs to be considered at the beginning of a fortification program.
- Storing fortified sugar for up to six months at temperatures of 22°C to 35°C and humidity levels of 70% to 85% saturation does not have a significant effect on the vitamin A activity.
- Vitamin A-fortified sugar can be directly heated to 100°C for periods of up to 15 minutes with no appreciable loss of activity. Vitamin A activity loss in heated syrups or jellies is 10-15%; dissolved at low pH values of 2-8 and heated, activity loss may reach 52%; in hot coffee or tea, loss is 1-2%; and in soft drinks, stability is very poor.

Special Considerations

- Sugar fortification programs need to ensure that the target population is effectively reached. At the same time, increased sugar consumption and excessive intake of vitamin A has to be avoided. This needs to be addressed when setting up regulations, enforcement/monitoring systems, social marketing and advertising.
- Complementary and/or more targeted interventions (e.g. vitamin A supplementation) are required to reach at risk-groups not consuming sufficient sugar on a regular basis, such as children under two years of age.
- Regular monitoring of compliance at points of manufacturing, retail, (re-)packaging and sales is essential, as well as the monitoring of sugar consumption patterns and vitamin A status of individuals at household level.
- Sugar is a very price-sensitive product. Fortified sugar needs to be affordable to target populations with low purchasing power. There is also a need to ensure that preference for fortified sugar remains unaffected by cheaper unfortified sugar (of domestic or international origin) and general developments in the international sugar market.
- Sugar fortification has been proven as a highly cost-effectiveness intervention, e.g. in Guatemala. Nonetheless, it must be carefully studied on a case-by-case basis.
- The sugar industry, including wholesalers and distributors, need to be involved in program development, planning and implementation.

Equipment

The vitamin A premix consists of sugar, vitamin A compound, unsaturated oil as a binder and an antioxidant to prevent peroxidation of the oil. The premix can be added manually into the centrifuges or automatically with more accuracy by feeders at different production stages; for best results, this should be done directly before packaging because humidity and temperature are lowest at this stage of production.

SALT

Food-grade salt is a crystalline product consisting predominantly of sodium chloride (>97% NaCl). It is obtained by mining of underground solid rock deposits or by solar evaporation of sea water, lake or underground brines. Iodization of salt began in the early 1920s in Switzerland and USA. Today, over 140 countries are implementing national universal salt iodization (USI) programs. The USI is recommended by WHO and UNICEF since 1993 as a safe, cost-effective and sustainable strategy to control the problem of iodine deficiency and resulting disorders. It implies the iodization of all salt for human (food industry and household) and livestock consumption.

Fortificants

Iodine, iron, fluoride

Iodine

Iodine and its salts (iodides or iodates) are volatile and reactive inorganic chemicals.

- Iodine stability is affected by oxidation due to moisture, humidity, heat and sunlight, or by impurities in the salt to which it is added.
- Sodium, calcium and potassium iodates or iodides can be used for salt fortification. Of those, particularly in hot and humid climates, potassium iodate (KIO3) is preferred to potassium iodide (KI) because it is more stable but more expensive; in such climates, KI would react with other sensitive vitamins. However, in countries with temperate climates, where the salt is purer and dryer, KI is also used as it is cheaper than KIO3.
- The addition of iodine to salt does not affect the salt's color, taste or odor.

Iron

Dual fortification of salt with iodine and encapsulated iron is efficacious in humans, improving both iron and iodine status.

- Suggested iron fortificants for salt: encapsulated ferrous sulfate, ferric pyrophosphate (2x dose)
- Iron fortificants can lead to increased rancidity due to oxidation of unsaturated lipids and unwanted color changes, i.e. darkening of salt to yellow or red/brown. Adverse sensory changes are highly variable and not always predictable. Thus, encapsulation is necessary which, however, increases the price of the fortified salt up to 30%.

Fluoride

Dual fortification of salt with fluoride and iodine is possible and practiced.

Technical Specifics

- Refined but also coarse washed salt can be iodized effectively.
- Iodization takes place after refining and drying and before packing. Two well established techniques used are a) wet method (very cost-effective): potassium iodate solution is dripped or sprayed at a uniform rate onto salt passing by on a conveyor belt; b) dry method (more demanding): potassium iodide powder or potassium iodate is sprinkled over the dry salt. The dry method requires salt made of small homogenous crystals and the thorough mixing of the salt after addition of the iodine compound to ensure an even distribution of iodine.
- Losses of iodine can be extremely variable as they depend on local conditions of production, quality of salt, climate, packaging and storage. Therefore, iodized salt must be as pure and as dry as possible, and it must be appropriately packaged in airtight bags.
- Level of iodization should be defined locally based on the estimated daily consumption of salt, the degree of iodine deficiency and the loss of iodine from producer to consumer. WHO suggested levels range from 14-65 mg iodine/ kg salt (see WHO Guideline 2014). Concentrations can be adjusted easily if conditions change.
- The use of iodized salt for some processed foods (e.g. bread) seems to be safe and without impact on quality and sensory characteristics. However, it cannot be extrapolated to other foods. Limited information is available on the reactivity of iodine and its salts with food components, bioavailability and the technological feasibility.

Special Considerations

- Local salt consumption has to be analyzed carefully as salt intakes vary substantially between countries. WHO recommends reducing salt intake to 5 g per day and processed foods (including condiments) are becoming the major source of salt for populations worldwide; however, they are mostly produced with non-iodized salt.
- Small scale salt producers and small re-packagers of unfortified salt need to be addressed to ensure the universal fortification of salt.
- Careful monitoring of salt iodine content at all levels and of individuals' iodine status is essential to ensure the efficacy and safety of salt fortification program.
- WHO discourages the use of salt as the vehicle for new fortification initiatives other than iodine and fluoride.

Equipment

Salt is iodized by spraying it with a potassium iodate or potassium iodide solution; 57 g of potassium iodate is required to iodize a ton of salt. At industrial scale, iodization is done with specialized spraying and mixing machines. Iodization machines may be manual or computerized and programmable, and are available at different capacities.

FISH SAUCE & SOY SAUCE

Fish sauce and soy sauce are liquid seasonings which are used in the preparation of Asian dishes. While soy sauce is part of the traditional kitchen in most Asian countries, fish sauce is mainly consumed in Vietnam, Cambodia, Thailand, Myanmar, Indonesia and Laos. Both are culturally accepted and widely used, independent of socioeconomic status and age group, in the respective countries. Soy sauce has been fortified with iron in China since the late 1990s. Fortification of fish sauce with iron started in the early 2000s, with initiatives in Vietnam and Cambodia. Both sauces were found to be appropriate vehicles for fortification to address the problem of iron deficiency and associated anemia. In Thailand, the double fortification of fish sauce with iron and iodine was successfully tested and is voluntarily double-fortified with iron (ferrous sulfate, FeSO4) and iodine (potassium iodate, KIO3). Nonetheless, iron is conventionally the most commonly used fortificant and double fortification with iron and iodine has thus far only been used in special initiatives and on a voluntary basis.

Fortificants

Iron, Iodine

Forms

- Various iron compounds are useable; their bioavailability increases with their water/diluted acid solubility, e.g.:
  - NaFeEDTA (ferric sodium ethylenediaminetetraacetic acid): water-soluble; highest iron bioavailability; high costs (up to 8% of the product price)
  - Ferrous bisglycinate: water-soluble; high costs
  - Ferrous sulphate: water-soluble; cheaper than NaFeEDTA, but leads to poor product stability (peptide precipitation) and organoleptic changes, particularly darkening of the color; preventable by adding citric acid for stabilization of iron compound
  - Microencapsulated iron: encapsulation (vegetable oils, starches, gelatines etc.) protects iron from absorption inhibitors; product cost will increase by 30%.
- Two iodine compounds are used for fortification: iodides (cheaper, more soluble, higher iodine content) and iodates (more stable in high moisture, high room temperature, sunlight, aeration, and the presence of impurities).
- Double fortification of fish sauce with iron (ferrous sulphate, NaFeEDTA, ferric ammonium citrate) and iodine (potassium iodide, iodate) is possible.

Technical Specifics

- Fortification takes places at the end of the production process; simpler technology compared to other staple foods as only a motor-driven mixing tank is required.
- Both types of sauce have high peptide contents. Peptides precipitate during storage when iron compounds are present, except for NaFeEDTA and ferrous sulfate heptahydrate with 0.1% citric acid (as chelator).
- The advantages of liquid forms are: they allow for even fortificant-distribution; the strong flavor of these sauces and, in the case of soy sauce, may be able to mask organoleptic changes (in taste or appearance) that may occur.

Special Considerations

Soy and fish sauce production has traditionally been a cottage industry in the Asian countries where they are widely consumed. Hence, the industry may be characterized as decentralized and having many small-scale producers contributing to the output and dietary intake of the local population. Such small-scale businesses may have limited resources (and access to resources) that can impact the quality of their production processes; for example, not being able to meet hygiene requirements would have an impact on food safety. Such a decentralized industry context would be unsuitable for fortification efforts.

Equipment

No specialized equipment is required; the fortificant premix is mixed into the fish/soy sauce in a non-corrosive holding tank prior to packaging/bottling.

BOUILLON CUBES

Since the start of the 20th century, a number of companies have been marketing industrially produced bouillon cubes as seasoning to enhance flavor and taste. As a source of salt, they are added to dishes instead of or in addition to regular table salt. Main ingredients are salt/sodium chloride (NaCl) (50-70%), dehydrated stock, solid vegetable fat, spices, and flavor enhancers, usually in the form of monosodium glutamate (MSG). Besides cubes, bouillon is also available as powder or granulate as well in various flavors. This low-cost cooking ingredient has reached high market penetration in Central and Western Africa and Asian countries, and more recently in the Caribbean and Latin America, with frequent and high consumption across all socioeconomic groups, in both urban and rural areas. Therefore, bouillon cubes are seen as promising vehicles for food fortification, globally. Generally, bouillon cubes fortified with iron, iodine and vitamin A are on the market. Where iodized salt is mandated for use in the production of processed foods, bouillon cubes are indirectly fortified with iodine. Bouillon cubes can be fortified with several micronutrients, and in previous years, iron, vitamin A, iodine and zinc have been used as fortificants. Currently, however, they are mainly fortified with iron and low levels of vitamin A and iodine.

Fortificants

Iron, mainly (vitamin A, iodine [indirectly through the use of iodized salt in the production of bouillon cubes] are used in low levels and zinc has been used in past fortification efforts)

Forms

- Vitamin A: retinyl palmitate
- Iron: NaFeEDTA; micronized ferric pyrophosphate plus tri-natrium; ferric pyrophosphate (FePP) plus tetrasodium pyrophosphate (NaPP) (46% increased iron bioavailibilty in humans compared to FePP alone).
- Zinc
- Iodine (from iodized salt)

Technical Specifics

- Cost of fortificant is the only cost related to bouillon cube fortification. Fortificants need to be in a dry powder form, which means a higher cost for vitamin A (retinyl palmitate) as this is originally in a liquid form.
- Limited research findings available on bouillon cubes fortification, e.g. organoleptic changes, loss during cooking, and effectiveness in view of the small amounts of the product consumed remain to be investigated.
- Iodine: limited data available on iodine losses; it was found that iodine concentration in bouillon cubes is minimally affected by prolonged storage; iodine is retained in bouillon broth independent of cooking time, opened/closed lid during cooking, bouillon concentration in water; iodine is absorbed into rice cooked in bouillon broth.
- Iron: challenges are iron bioavailability, stability of the cubes in hot and/or humid climates, sensory changes (e.g. color, taste) and/or segregation. NaFeEDTA is recognized to be the best fortificant because of high bioavailability and small amounts consumed. However, it can lead to organoleptic changes (color), particularly due to interaction with herbs in the bouillon cubes.

Special Considerations

- The bouillon cubes industry is relatively consolidated and formalized in most cases, which makes regulation and monitoring more feasible.
- Universal Salt Iodization (USI) Programs need to incorporate (directly or indirectly) iodine-fortified bouillon cubes as bouillon cubes are an important source of the population's salt intake.

Equipment

No specific equipment is needed because the premix is mixed into the bouillon cube mass before pressing into cubes.

MARGARINE

Margarine fortification with vitamin A and D started as early as 1930, when Denmark fortified margarine with vitamins A and D, and has been on-going since. Margarine is produced through hydrogenation of liquid vegetable oils into solid fats and fortificants are added to it during its oil phase.

Fortificants

Vitamin A, vitamin D and, sometimes, vitamin E

Forms

- Vitamin A palmitate; cholecalciferol (vitamin D3)

Technical Considerations

- The premix, which is a blend of vitamins A and D in oil phase, is mixed with warm oil and then added to the margarine before the emulsifying process.
- Vitamin A is quite stable in margarine during both manufacturing and storage. Recommended storage is at 5 degrees Celsius in a refrigerator. Since a functional cold chain is required for optimal storage, margarine fortification in least-developed regions may be challenging.
- Cooking methods influence vitamin A stability; heating margarine to high temperatures will result in a loss of up to 50% of the vitamin A, whereas vitamin A is more stable during the baking process of bread, biscuits, cakes (only 20% loss).

Equipment

No specific equipment is needed as the premix is added into the motor-driven, automated mixing tank that is used to produce the margarine. Vitamin E may be added to margarine as a nutrient but the level needs to be well balanced as too much of it encourages oxidation..

FRUITS AND VEGETABLES SECTOR

Creating Markets, Creating Opportunities

Context

In the context of food fortification, the relevant outputs from the fruit and vegetable sector include ready-to-consume packaged derivatives, such as processed fruit juices and vegetable purees. These types of products have not been used in public health-oriented fortification efforts. In general, their development and introduction to the market has been driven more by commercial motivations (e.g. product differentiation, market positioning, health claims) and, while they may contribute to improved nutritional status, their impact on health is generally left untracked and, hence, their relevance to public health efforts (i.e. through fortification of multiple products) is limited. Nonetheless, it is generally better to fortify these products when feasible as it would deliver a healthier product to the market.

There are many examples of voluntarily-fortified fruit and/or vegetable juices, vegetable soups and purees on the market. Fruit, vegetable or mixed fruit and vegetable juices may be enriched with nutrients lost during processing, while similar purees may be fortified with additional nutrients and targeted to specific consumer segments, e.g. elderly people in long-term care, for functional benefits.

FRUIT JUICES

The fortification of fruit juices with vitamin D, calcium and vitamin C as well as with probiotics has become more common over the last decade, making fruit juices a potential good source of these nutrients for individuals.

Fortificants

Vitamin C, vitamin B2 (riboflavin), vitamin B1 (thiamine), vitamin B9 (folic acid), vitamin B12 (cobalamin), vitamin D, vitamin A, vitamin E, calcium, iron.

Since many fortificants with each different characteristics are used, some points on their stability, retention and bioavailability are warranted:

- Ascorbic acid (vitamin C) stability is subjective to high heat and humidity, presence of metal ions as well as light and air exposure. It shows greater loss over time in comparison to riboflavin and thiamine.
- Folate has better bioavailability in its synthetic form, folic acid.
- Vitamin D has good stability and bioavailability in fortified orange juice.
- Presence of vitamin E has been shown to increase the bioavailability of vitamin A.
- Calcium citrate malate is a soluble calcium salt that has good bioavailability in fortified apple and orange juice.
- Vitamin C will counter the inhibitory effects of calcium and phytate on iron absorption.
- Iron salts may stabilize cobalamin, but can accelerate vitamin C loss, impact the flavor profile, cause metallic-off flavors and cause discoloration of certain pigments.

Special Considerations

- There have been concerns voiced on the high sugar content of fruit juices. Increased consumption of fortified fruit juices should therefore not be a goal of fortification of such products; rather, the approach should be that, if anyone wants to drink a fruit juice, it is relatively more beneficial to choose a fortified product over a non-fortified alternative.
- Translucent packaging may result in degradation of juice quality and nutritional content during retail display under fluorescent or LED lighting. Packaging also needs to be carefully considered when fortifying with vitamins that are sensitive to light, heat and/or oxidation.
- For children aged two and younger, fruit juices should never be positioned as suitable alternatives to breast milk or cow's milk.

Technical Specifics

- Vitamin C (also known as ascorbic acid) may be added to a juice product as a technical antioxidant to inhibit browning and/or prevent oxidative flavor deterioration. It is only considered as a fortificant when added to compensate for seasonal or processing variations and/or increase vitamin C content of the fruit juice.
- Fruit juices are typically acidic in nature and require pasteurization to kill any potentially harmful microorganisms, prevent discoloration and extend shelf lives. Loss of heat-labile vitamins B and C, thiamine, folic acid and ascorbic acid can be expected after thermal treatment.
- Juice can either be pasteurized and stored as single-strength juice or concentrated and stored shortly after extraction.
- Right before being bottled, the juices (single strength or concentrate) are blended together and micronutrient additives are typically incorporated at this stage. The juice is then filtered, pasteurized and filled into bottles whilst still hot. The containers are cooled quickly after being filled.
- Juices may be flash pasteurized (pasteurized very quickly and cooled quickly) to sterilize the juice while minimizing flavor changes and loss of micronutrients through heat treatment.
- Vitamin loss occurs over time in retail environment. Storage trials should be carried out to ensure that vitamin 'overages' added to fruit juices are sufficient to ensure that the nutritional claim can be met at the end of its shelf life and at point of consumption.

Equipment

No specialized equipment is needed for fortification as the premix can be added using equipment already being used on the production line.

VEGETABLE SOUPS & PURÉES

Canned vegetable soups, targeted to the general market, may be enriched to ensure nutrients lost during processing are compensated for in the final product; they may also be fortified with additional micronutrients.

Commercially-available vegetable purées are catered to infants and individuals suffering from dysphagia, who are typically the elderly. Vegetable purées for dysphagia diets are hardly ever fortified - if the variety of micronutrients available in the vegetable and/or fruit blend are insufficient in meeting the individual's needs, micronutrient intake is increased through supplementation or introducing other fortified foods. Fortification of puréed foods for the elderly with folate and vitamins B12 and D has been suggested but has not been extensively researched or carried out.

Vegetable purées for babies are niche products targeting parents with higher purchasing powers. With such products, heavy emphasis is placed on having minimally processed, healthy products with words like 'organic', 'additive-free' and 'preservative-free' to appeal to this target audience. Many baby purée products are not fortified as they already contain sufficient levels of vital micronutrients, but the few that are fortified have added natural or synthetic DHA, ALA, choline, zinc, vitamin A, C and/or E, and are marketed as being essential in promoting healthy growth and development or even supporting brain health.

Fortificants

Vitamin C, vitamin E, calcium, DHA, ALA, choline, zinc, vitamin A

Special Considerations

- Nutritional requirements for infants and the elderly.
- Levels of naturally occurring micronutrients in purées, especially in a vegetable and/or fruit blend.
- Dysphagia
- Palatability

Technical Specifics

- Aseptic technology: Rapidly thermally-pasteurized purées are filled aseptically into sterile packaging, which is then hermetically closed; such products have high shelf-stability.
- Thermal pasteurization results in greater inactivation of browning enzymes than cold pasteurization, but causes greater destruction of anthocyanins, vitamin C and sensory quality.
- Cold pasteurization uses high pressure processing to reduce microbial load and maximize nutrient, flavor and color retention; in-pack processing is possible.
- Cold pasteurized products require refrigeration and are less shelf-stable than thermally pasteurized purées.

Equipment

No specialized equipment is needed for fortification as the premix can be added using equipment already being used on the production line.

Food Fortification
NON-DAIRY BEVERAGE SECTOR

Context

The non-dairy beverage sector has recently received more attention because of the trend toward replacing animal protein and milk with plant-based proteins for cost, environmental and health reasons (e.g. allergy to milk proteins, lactose intolerance, perceived health benefits). Since cow's milk has been regarded as the gold standard for the most optimal nutritional beverage for all age groups, non-dairy beverages are designed to imitate the properties of cow's milk; however, since plant proteins are not complete proteins (i.e. plant proteins generally do not contain all nine essential amino acids found in animal proteins), except for soy, most plant-based protein beverages must be fortified or use a combination of different plant-based proteins to achieve a complete amino acid profile.

Non-dairy beverages (or plant-based milk alternatives) are created by disintegrating the plant material extracted in water. The liquid is later homogenized to achieve a particle size distribution of 5 μm to 20 μm to mimic the appearance of cow's milk. Typically, non-dairy beverages do not share the same nutritional profile as cow's milk. They are commonly fortified with protein, calcium, vitamins A, D, B2 and B12, most of which are found abundantly in cow's milk. The lack of general consensus on the amount and kind of fortification of commercially available non-dairy beverages is evident – some non-dairy beverages are not fortified at all while others are heavily fortified to closely imitate the nutrient content of cow's milk. Fortification of a wide variety of non-dairy beverages within the range of permitted vitamins and minerals are voluntary in the U.S, Europe and Australia.

In a number of developing countries, particularly in Asia, the consumption of home-made soy-based milk beverages are a traditional part of the local diet. While this makes such beverages a potential carrier for micronutrient fortification to improve public health, it is also possible in such markets that the industry is highly decentralized, with small or home-based businesses having a sizeable share of the market. Such a production landscape presents challenges to managing quality in fortification efforts.

Relevance to Public Health

The raw material cost of some non-dairy beverage alternatives (e.g. cereal- and legume-based) may be lower than that of cow's milk, making them attractive for public health efforts to reduce and prevent population micronutrient deficiencies. Others (e.g. nut- and seed-based alternatives) would be prohibitively expensive for such efforts, hence their market positioning as premium products aimed at higher-income market segments.

Types of Non-dairy Milk Alternatives

There is no stated definition and classification of non-dairy milk alternatives in literature. A general classification of non-dairy milk into five categories is attempted in Sethi et al (2016) as follows:

- Cereal-based: Oat, Rice, Corn, Spelt
- Legume-based: Soy, Peanut, Lupin, Cowpea
- Nut-based: Almond, Coconut, Hazelnut, Pistachio, Walnut
- Seed-based: Sesame, Flax, Hemp, Sunflower
- Pseudo-cereal-based: Quinoa, Teff, Amaranth

Fortificants

Protein, calcium, vitamin A, vitamin D, vitamin B2 (riboflavin), vitamin B12 (cobalamin)

Forms

- Calcium in the form of calcium carbonate in fortified non-dairy beverages has the equivalent bioavailability of calcium in cow's milk.
- The other fortificants are chosen in specific forms, together with stabilizers to achieve stability in their respective product formulations and characteristics, such as dry vitamin A palmitate, dry vitamin D3 stabilized with tocopherol, etc.

Special Considerations

- Specific nutrient profiles (i.e. carbohydrates, proteins, fats, cholesterol, vitamins, minerals) of non-dairy milk alternatives and associated allergies (e.g. gluten, soy, nut) need to be considered in light of population-level health issues.
- The prevalence of milk protein allergy and lactose intolerance, ethical concerns (i.e. living conditions, food quality, and routine use of antibiotics and hormones in cows) and the practice of vegetarianism/veganism in the target population drives demand for non-dairy milk alternatives.

Technical Specifics

Particle size and product stability is largely dependent on the nature of the raw material, method used to break down the plant material and storage conditions.

- Oat and rice milk: Their high starch contents result in poor emulsion stability. Enzymatic hydrolysis of starch in oat and rice with amylase and amylase/glucosidase respectively will prevent gelatinization during thermal treatment.
- Oat milk: Phytic acid, an anti-nutrient found in considerable amounts, is treated with phytase to liberate inorganic phosphate from phytic acid, improving the nutritional value.
- Soy milk: Beany flavor can be deodorized by vacuum treatment at high temperature, hot grinding, blanching, alkaline soaking and use of soy protein isolates and flavoring compounds. Heat inactivation of growth inhibitors can cause dissociation, denaturation and aggregation of soy protein, negatively impacting protein solubility.
- Peanut milk: Beany flavor can be deodorized by defatting, roasting, alkali soaking or steaming. Emulsion stability can be improved by heating, homogenizing, and addition of stabilizers and emulsifiers.
- Sesame milk: Decortication of sesame seeds removes anti-nutritional factor oxalate and helps to reduce bitterness. Alkali soaking, roasting, defatting, germination and microwave heating can improve the solubility of sesame proteins in water. Bitterness and chalkiness can be removed by roasting and alkali soaking.

Equipment

No specialized equipment is needed for fortification as the premix can be added using equipment already being used on the production line.

Food Fortification

PLANT-BASED PROTEINS FOR FORTIFICATION

International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Context

In the public health context, inadequacy of protein intake as a contributor to stunting in children is an area of research that has recently re-emerged as topic of importance. While stunting reduction/nutrition improvement efforts have, in recent decades, shifted to a focus on micronutrients, experts are now revisiting the role of inadequate levels of key amino acids, such as choline, lysine and others, in childhood stunting. Animal-source food products, which are generally better sources of protein than the relevant plant-source foods, are also generally more expensive food products; hence the ability to enrich/fortify food vehicles with protein can be a useful complement to public health strategies to achieve nutrition improvement in key target groups. Adequate protein consumption among elderly populations is also of increasing concern and alternative plant proteins may have a role in addressing this.

Global trends such as increasing population growth and increasing affluence in many developing countries have spurred demand for protein consumption, in food as well as beverages. While animal-source proteins, such as whey (discussed in Leaflet 10) and casein from cow's milk, have traditionally been used to fortify products, soy has long been used to support protein intake in humanitarian and emergency contexts, and lesser known alternative protein sources have become more accessible in recent years.

Animal-source proteins contain the nine essential amino acids needed by humans and available only through dietary intake, while plant proteins by and large have incomplete amino acid profiles, with the exception of soy. Plant proteins are nonetheless a good source of branched-chain amino acids (BCAAs), such as leucine, isoleucine and valine, which promote muscle development and increase endurance. Soybeans, baked beans, lima beans, lentils, brown rice, whole wheat, corn and nuts such as almonds and cashews are good sources of branched-chain amino acids.

With increased knowledge on alternative protein sources, the concept of protein quality was developed as a means of evaluating the digestibility and quantity of essential amino acids for providing the proteins in correct ratios for human consumption. Protein digestibility-corrected amino acid score (PDCAAS) is a method of evaluating the quality of a protein based on both the amino acid requirements of humans and their ability to digest it.

SOY

Soybean has been a plant protein of choice and is high in leucine, though not as high as whey protein. Nonetheless, because it is a complete protein source and its cost is relatively low, soy has been the most popular plant-based protein alternative on the market.

For nearly 50 years, various formulations of corn soy-based and wheat soy-based fortified blended foods (FBFs) have been used in humanitarian and emergency relief activities, particularly by the World Food Programme (WFP). Local variations of CSB products and other FBFs are used as complementary foods throughout the world. An improved formulation of CSB, known as CSB Plus, has been formulated by WFP based on World Health Organization (WHO) guidelines for the treatment of moderate acute malnutrition. CSB Plus is a cooked blend of milled, heat-treated corn and soybeans, fortified with a vitamin and mineral premix. The ingredients are partially cooked through wet or dry extrusion or roasting.

Other Alternative Protein Sources

Besides soy, a number of other plant-based protein alternatives, varying in cost, have been used in fortified products. These plant-based protein alternatives include pulses (dry beans, dry peas, chickpeas and lentils), seeds (hemp, chia, flaxseed), ancient grains (amaranth, quinoa), algae (spirulina) and moringa oleifera leaf. Potato is also a plant-based source of protein that, like soy, has a complete amino acid profile.

More recent developments in alternative protein sources to monitor are fish protein concentrate/powder (FPP) and insect protein powder. FPP is processed from underutilized fish species and raw fish parts are considered to be a low-cost, high quality protein that has sensory properties similar to dry fish. Popular in Japan and gradually becoming accepted in China, FPP can be incorporated into food products to improve the protein quality and quantity of low-income diets, especially in countries where consumers are purchasing more energy dense, nutrient poor processed foods. Likewise, insect protein powder produced from insects bred for human consumption (a part of the traditional diet in some countries) is rich in vitamins, minerals, fiber and protein, and the relatively low production cost makes it suitable for use in low-income settings or for public health outcomes.

Key Considerations in the use of Alternative Proteins

Products fortified with alternative proteins with incomplete amino acid profiles often use a combination of two or more of these proteins to achieve a more complete amino acid profile. A key example is the combination of proteins from pulses and wheat, which come close to a complete amino acid profile. Based on this understanding, pulses are increasingly used in bakery products, such as bread. However, protein fortification of bread and other yeast leavened baked products is not straightforward; many important aspects of a dough, such as dough handling, mixing times, crumb structure and other attributes, are affected by the choice of protein(s) added. There is also a risk of an increase in acrylamide, a chemical that naturally forms in starchy food products during high-temperature cooking, including frying, baking, roasting and industrial processing, at +120°C and low moisture. While naturally present in raw foods in very small amounts, acrylamide poses a risk of toxicity or cancer in larger amounts.

Besides baked goods, foods in which alternative proteins are used include beverages, bars, seasoning mix, crackers, crisps, snacks, thickeners, sauces and vegetarian cheese. However, alternative proteins may be harder to incorporate into foods or beverages and a number of considerations arise in identifying the most suitable protein source for a particular application:

- Consumer acceptance (e.g. insect protein may not be well-accepted in mainstream applications)
- Dietary requirements and allergen control
- Technical factors such as flavor, color and texture
- Properties required in the final product (e.g. elasticity, viscosity, emulsifiability)
- Interactions with other ingredients

Alternative Proteins in Traditional Diets

In India, local diets often use a combination of cereals and pulses, complementing the limited amino acid lysine and methionine (dal rice, khichadi, chapatti dal combination). Dals and pulses (such as lentils, mung beans, cowpeas, chickpeas and green peas) are added to vegetables to increase the protein content of the food. Indian households also add roasted soybean to wheat grains to produce flour with increased protein content. Furthermore, the addition of nuts and oilseeds to vegetable preparations is a way to increase the protein content of the preparation. The most popular nuts and oil seeds are ground nuts, and sesame, pumpkin and sunflower seeds. Besides increasing protein content, these ingredients are added to traditional preparations to enhance flavor and palatability.

In Nigeria, African yam bean (a high protein source that is also rich in fibre, carbohydrate and minerals, such as phosphorus, iron and potassium) has been used to fortify casava fufu flour, a traditional staple food that is otherwise deficient in protein and other nutrients. A study conducted on this recommended enrichment or fortification of cassava fufu flour with African yam bean flour to increase protein intake in cassava-consuming areas of Nigeria, where protein malnutrition is prevalent. Early-stage efforts are underway to explore protein enrichment of other food products with yam bean, including maize flour.

Creating Markets, Creating Opportunities

Context

Micronutrient deficiencies are typical in populations that rely mainly on starchy staple foods (e.g. cereals, roots and tubers), where the lack of dietary diversity results in a lack of sufficient essential minerals and vitamins required for proper growth and body function. Biofortification, the process of increasing the density and bioavailability of nutrients in crops through conventional plant breeding, agronomic practices and genetic engineering, is one of the strategies used to combat micronutrient deficiencies, particularly in rural communities, infants, young children, pregnant women and breastfeeding women.

Deficiencies of zinc, iron and vitamin A increases people's vulnerability to illness and infections, and in serious cases be the cause of blindness, mental retardation, stunting and death. It has been estimated that the health benefit-to-cost ratio of biofortified crops is US$17 of benefits to US$1 invested. Staple food crops are biofortified with zinc, iron and vitamin A such that when regularly consumed, the crops will prompt a quantifiable improvement in nutritional status.

By targeting crops that are widely consumed by locals, the intention of biofortification is not to change dietary habits. In addition to being more nutrient-dense, it is important that biofortified varieties should be high yielding, climate-resistant, pest-resistant and profitable for farmers. Acceptance is also dependent on end-use characteristics such as color and taste.

Unlike conventional food fortification, biofortification works best in improving nutritional status in rural, resource-poor regions where processed foods are unavailable or not affordable. While there are many staple food crops currently being evaluated for their suitability for biofortification with zinc, iron or vitamin A, biofortified wheat, rice, cassava, orange sweet potato, maize, pearl millet and bean varieties have been approved and are available in selected countries.

It would be inaccurate to assume that farmers that grow biofortified crops will retain some of the biofortified foods for their own consumption. There is a wide variation in the amount of biofortified crops kept for self-consumption and selling, differing greatly between vulnerable farmer households. There is a lack of studies that investigate the relevance of growing biofortified crops and reducing micronutrient deficiencies in farmer households.

Fortificants

Vitamin A, iron, zinc

Special Considerations

- Consumer acceptance of biofortified varieties, particularly pro-vitamin A varieties, which are yellow or orange in comparison to the whiter color of the non-biofortified varieties.
- Desirable agronomic traits.
- Genetically-modified foods controversy (if genetically engineered).
- Seed market network suitability for large-scale dissemination of biofortified varieties.
- Distinguishing biofortified varieties from its conventional counterparts.

Technical Specifics

- Zinc wheat varieties are available in India and Pakistan. They are high yielding and disease-resistant, and provide up to 50% of daily zinc needs.
- Zinc rice varieties are available in Bangladesh and India. They are high yielding, disease- and pest-resistant. They provide up to 60% of daily zinc needs.
- Pro-vitamin A cassava varieties are available in Nigeria and the Democratic Republic of Congo (DRC). They are high yielding, disease- and pest-resistant. They provide up to 40% of daily vitamin A needs.
- Pro-vitamin A orange sweet potato varieties are available in Uganda. They are high yielding, virus-resistant and drought tolerant. They provide up to 100% of daily vitamin A needs.
- Pro-vitamin A maize varieties are available in Nigeria and Zambia. They are high yielding, disease- and virus- resistant and drought tolerant. They provide up to 25% of daily vitamin A needs.
- Iron pearl millet varieties are available in India. They are high yielding, mildew-resistant and drought tolerant. They provide up to 80% of daily iron needs.
- Iron bean varieties are available in the DRC, Rwanda and Uganda. They are high yielding, virus-resistant as well as heat and drought tolerant. They provide up to 50% of daily iron needs.
- It costs approximately US$75 million to provide 37.5 million pre-school children in Bangladesh, India and Pakistan one year of vitamin A supplementation. The same amount can buy sufficient iron fortification for a year for the sample populations. It is also the cost of developing and disseminating iron- and zinc-rich rice and wheat varieties for South Asia, which requires minimal recurrent costs.
- The initial one-time investment from the private sector is typically fixed to develop nutrient-rich biofortified varieties, keeping the recurrent costs at a minimum. Biofortified germplasms can be shared globally.
- Biofortified seeds are typically competitively priced with regular varieties to maintain affordability to subsistence and smallholder farmers. They can be distributed to farmers via seed companies or non-governmental organizations.
- Hybrid seeds must be purchased by farmers fresh for each planting season to maintain high productivity and agronomic traits.
- Crops like sweet potato, cassava, pearl millet and beans, can be replanted yearly from stem and root cuttings.
- Self-pollinated crops include iron beans, zinc rice and zinc wheat. Once self-pollinated crops are developed and grown, their seeds can be multiplied, reproduced and shared among the poor and new farmers. While farmers can save the seeds and replant them every year, it is advisable for them to periodically replace their seed to maintain its desirable agronomic traits.
- In addition to the fact that biofortified varieties produce higher yields, the cost difference between biofortified seeds and non-biofortified varieties should be negligible in the long run.

Equipment

No equipment is needed on the part of farmers or food manufacturers as biofortified seeds are bought like regular seeds from specialist companies and, as such, are planted and processed in the same way as normal seeds.

Context

The fortification of milk and dairy products has surged in recent years. While liquid milk has been fortified as early as the 1930s, other dairy products such as yoghurt, fresh ‘fromage frais’ and cream cheese now lend themselves to fortification that is technically quite simple. Due to their high viscosity, sedimentation does not occur in these products.
The dairy sector is also a source of whey protein, which can be used to increase the protein content of suitable food vehicles that are otherwise low or lacking in protein. The claim of ‘high protein’ content in a fortified food product emerged in the medical niche, before it became more accessible when whey protein was used to fortify Greek yogurt. Eventually, the use of whey protein in supplements or beverages targeting the diet and sports market made it more popular. Today, more diverse processed food products contain additional protein from whey (snacks, beverages, RTE meals, etc.) as well as other alternative (i.e. non-animal origin) protein sources.

MILK & YOGURT

Milk fortification has historically been commonly adopted as a means of preventing rickets and proven successful in doing so. Currently, vitamin A fortification of low fat and skimmed milk, and vitamin D fortification of all milk is mandatory in Canada, whereas milk fortification with vitamins A and D is almost universal in the United States. In the 1930s, Europe followed in the footsteps of the United States in milk fortification but ceased milk fortification efforts with vitamin D in the 1940s and 1950s. To date, Sweden is the only EU member to mandate milk fortification with vitamin D. Milk fortification is less commonly practiced in Asia but voluntary fortification is on-going. Butter and ghee (clarified butter), which are derived from milk, can also be fortified. In India and Afghanistan, there are standards on ghee fortification.
It is also possible to fortify powdered milk through the addition of dry vitamin preparations to the milk powder as well as by vitamin addition to the liquid milk just prior to spray drying. Effective mixing requires the initial dilution of the vitamin mixture with a suitable quantity of milk powder, followed by mixing into the bulk. Particle size and density are important and must be considered in order to prevent separation of the components during storage.

Globally, yogurt fortification with vitamins A and D is less conventional. However, the growing popularity of yogurt consumption makes yogurt fortification a potential strategy to complement existing approaches in alleviating malnutrition as a functional food. Nevertheless, the sensory properties of fortified yogurt should not be influenced by using high concentrations of minerals. A possible way to enhance the level of minerals in dairy products is through micronization of the minerals as ultrafine particles ease dispersion, improve mouth feel and texture, and ultimately aid acceptance of the fortified products. For liquid dairy products, such as fresh milk, however, special forms of insoluble mineral fortificants are needed and have been innovated in recent years by the functional ingredient industry.

Fortificants

Vitamin A, vitamin D, vitamin C, folate (vitamin B9), calcium, iron, zinc, magnesium, DHA omega-3 fatty acid

Forms

- Vitamin A and D concentrates are available in oil soluble or water dispersible forms as retinyl palmitate (vitamin A) and vitamin D3 (and less commonly as vitamin D2), respectively.
- Tricalcium citrate, trimagnesium citrate nonahydrate or zinc citrate are preferred for yogurt fortification as dissolution is not required and negative effects on taste dominate at higher concentrations.
- Strain-dependent folate production typically from Bifidobacterium and Lactobacillus species.
- UHT milk can be fortified with DHA but at low levels as it can otherwise cause organoleptic changes. DHA in powder form is normally used as adding DHA in its original oily form requires additional emulsification and stabilization equipment and processes to minimize any separation.

Some discussion on stability, retention and bioavailability of fortificants used in milk are included below:
- Potency of vitamin concentrates degrade over time.
- Oil-based concentrates should not be stored under refrigeration unless recommended.
- Water-dispersible concentrates typically have a shorter shelf-life than oil-based concentrates.
- Good bioavailability and stability (>90 percent) of vitamin D3 in fortified milk and yogurt.
- Vitamins A and D have similar fat solubility and sensitivity to light, moisture and oxidation.
- Vitamin D is more thermally robust than vitamin A and degrades slower than other vitamins in milk.
- Vitamin A degrades rapidly when exposed to light and at faster rates in skimmed/low-fat milk than in whole milk.
- Good bioavailability of folate and iron in fortified yogurt.
- Presence of calcium in yoghurt inhibits heme and non-heme iron absorption, but the use of vitamin C can increase iron absorption due to its reducing power and chelating action.
- The low pH conditions in yogurt production render it unsuitable for fortification with vitamin A.
- Water soluble B-vitamins for fortifying yogurt are best used in a coated form, protected for odour and flavor considerations.
- When vitamins are added to the yoghurt by addition to the base, some vitamin loss can occur through metabolism by fermentation microorganisms (O'Brien and Roberton, 1993).

Special considerations

- Milk
  - Prevalence of lactose intolerance
  - Sub-optimal production
  - Natural levels of vitamin A in milk
  - Degradation of milk quality and nutritional content during retail display under fluorescent or LED lighting
- Milk and yogurt
  - Cold chain infrastructure
  - Adulteration of dairy and dairy products
  - Inhibitory effect of calcium on iron absorption
  - Influence of fortification on sensory profile and chemical oxidation

Technical Specifics

- All vitamin concentrates must be added before pasteurization.
- Batch or continuous fortification: Addition of vitamin concentrates into the pasteurizing vat, High Temperature/Short Time (HTST) balance tank, or continuously into the pipeline.
- Batch fortification requires accurate measurement of the fortified milk volume and vitamin concentrate; the use of more diluted concentrates improve accuracy.
- Oil-based vitamin concentrates must be added into milk flow after the cream separator.
- Water-dispersible vitamin concentrates are desirable if vitamins must be added before fat standardization.
- Vitamin concentrates should ideally be added after separation and standardization to avoid under/over-fortification.
- Homogenization ensures even distribution of vitamins throughout milk.
- Yogurt can be prepared using fortified or unfortified milk.
- Minerals are generally applied to yogurts via the fruit preparation as the low pH value and high fruit acid concentration increase mineral solubility.

Equipment

No specialized equipment is needed for milk fortification. The premix, in powder form, is solved in water and added to the milk in a large, preferably motor-agitated tank to allow homogenous distribution. For yogurt, the premix is added in a similar process while making the yoghurt. The exception to the above is if DHA is added in its original oily form, in which case an emulsifier and stabilizer are needed to minimize separation.

WHEY

Milk is made of two proteins, casein and whey. Whey protein is formed as a by-product of cheese making. Whey protein is considered a complete protein as it contains all nine essential amino acids and it is low in lactose content.
Protein powders derived from whey have driven new nutrition trends and are used to enhance muscle growth among athletes. They also help infants to develop, elderly people to gain weight, and aid in feeding people during hunger catastrophes. At the same time, whey-based products are used as functional ingredients in bakery and in various kinds of processed foods.
In the sports and fitness market, protein fortification has long been established as providing many nutritional benefits. Aside from commercial applications to modify the organoleptic profiles of baked goods and confectionary, added whey protein promotes muscle growth, muscle recovery and satiety. It is often preferred over casein, another milk protein, as a dietary supplement due to its faster absorption in the stomach and greater initial rate of muscle protein synthesis, which may be attributed to its higher leucine content.

Use as a Fortificant

In this context, whey protein, the protein portion of whey, is the fortificant. Whey protein is available as whey protein concentrate, isolate and hydrolysate. Whey protein typically comes in four major forms: concentrate (WPC), isolate (WPI), hydrolysate (WPH) and Native Whey.

Technical Specifics

- Whey Protein Concentrates: Concentrates have typically a low (but still significant) level of fat and cholesterol but, in general, compared to the other forms of whey protein, they are higher in carbohydrates in the form of lactose – they are 29 percent to 89 percent protein by weight.
    - 35 percent to 80 percent protein in dry matter
    - Production: Ultrafiltration, diafiltration or reverse osmosis of liquid whey
    - >60 percent protein: Evaporation is avoided to prevent heat damage to proteins
    - >80 percent protein: Diafiltration is needed to remove lactose, ash and mineral
- Whey Protein Isolates: Isolates are processed to remove the fat and lactose — they are 90%+ protein by weight. Like whey protein concentrates, whey protein isolates are mild to slightly milky in taste.
    - >92 percent protein in dry matter
    - Production: (1) Microfiltratration, diafiltratration, high concentration nanofiltration and spray drying, or (2) ion exchange chromatography
- Whey Protein Hydrolysates: Hydrolysates are whey proteins that are predigested and partially hydrolyzed for the purpose of easier metabolizing, but their cost is generally higher. Highly hydrolyzed whey may be less allergenic than other forms of whey.
    - Production: enzymatic hydrolysis
    - Digests whey proteins into amino acids and peptides for faster absorption in the stomach
- Native whey protein is extracted from skim milk, not a byproduct of cheese production, and produced as a concentrate and isolate.

Special considerations

- Whey protein purity
- Presence of ‘filler’ ingredients
- Lactose intolerance
- Increased protein requirement due to age-related muscle loss or resistance training
- Post-resistance training muscle recovery

Notes to the table

1. The table in Leaflet 11 is primarily based on data form the Global Fortification Data Exchange (GFDx, https://www.fortificationdata.org/), which tracks and standardizes global efforts in food fortification, specifically for vegetable oils, flours (wheat, maize), rice and salt. These are typically the food vehicles used for mass fortification programs to address micronutrient deficiencies of public health concern. Besides these food vehicles, other food products that are fortified at smaller scale, for very specific target groups or for niche markets are not systematically nor centrally tracked; therefore, these are generally not included in the table.

2. Additional information is included from other sources, particularly where the GFDx does not have complete information or does not track the particular food vehicle, but it has relevance to a sector highlighted in this leaflet series. These alternative resources are (mainly) the European Commission's Food Fortification Global Mapping Study 2016 as well as personal communication from knowledgeable sources. An example of food vehicle fortification data from these sources are sugar and bouillon cubes. Information from these sources are differentiated in the table with red font.

3. The fortificants listed in the standards included represent what each country's/region's authorities have approved with regard to nutrients (and in some cases, allowable forms) and inclusion levels. Within these options, food and beverage manufacturers still have to make decisions on the formulation (with regard particularly to the best form for a given food vehicle application/matrix) for the premix that results in the optimal outcomes for bioavailability, stability, organoleptic/sensory impacts, cost (to the producer and to the consumer) and other important factors.

4. This summary table is a ‘living’ document as standards and regulations are regularly reviewed and may be updated. Therefore, the table should be used as guidance and the latest information should be confirmed at the country level.

Context

Food fortification is one of the most efficient and cost-effective ways to bring vital micronutrients to the population while no food habit changes are needed. However, there are certain requirements that need to be met in order to make food fortification a success and a viable complementary strategy for improving micronutrient status and preventing severe micronutrient deficiencies in both vulnerable and affluent segments of the population.

There are several touch points for making food fortification optimal along the food fortification value chain, starting from the sourcing of the raw materials for the food vehicle itself as well as the sourcing of the premix ingredients, the way the fortified food is produced, distributed and finally consumed.

Sourcing

- Food vehicle
- Fortificant (premix)

Production

- Food matrix
- Fortificant
- Fortification process

Distribution

- Fortificant stability
- Logistics

Consumption

- Food preparation methods
- Fortified food quality

While the above 'simplified' fortification value chain identifies specific components, it should be noted that Quality Assurance and Quality Control (QA/QC) is another component that takes place across these different touchpoints but is implemented by relevant stakeholders at each touchpoint. The cost implications of establishing efficient QA/QC across all the components of the value chain are often underestimated; companies need to invest in setting up internal QA/QC systems, train employees; governments need to put in place independent reference labs, valid quality tests and an efficient enforcement system. Monitoring and evaluation of food fortification efforts are also required and costs will need to be borne by governments if nutrition improvement of the population is the desired outcome.

Sourcing

This refers to both, the sourcing of the raw materials for i) the food itself which will be fortified as well as the sourcing of ii) the premix ingredients. (Note: premixes are preferred to purchasing 'straight' vitamins and minerals separately as the ingredient supplier can usually optimize the formulation for the needed application.)

a. Certain food vehicles that are chosen to be fortified need to have a specific biochemical consistency after processing and a high quality in terms of being pure and uncontaminated with other substances (e.g. molds, such as aflatoxins, in the case of raw maize or rice, or side products) prior to fortification. This applies in particular to refined oil and salt. Refined oil prior to fortification needs to have a peroxide level of less than 2 mgEq/kg and an acid value of 0.6 mg KOH/g at production to prevent micronutrient loss and degradation. Salt needs to be pure and not contaminated with other particles, such as impurities stemming from a sub-optimal salt production process.

b. Premix ingredients such as the raw ingredients of vitamins and minerals need to be optimal as lower quality inputs will influence their stability, bioavailability and, ultimately, impact on consumers' nutritional status. Premixes should be bought from accredited premix suppliers with valid Certificates of Analysis assuring the quality of the premix.

c. In regard to the QA/QC component, foods that have been chosen as the food vehicle for fortification need to be produced under internationally-recognized manufacturing standards, such as Good Manufacturing Practice (GMP) and other related production and quality standards (e.g. HACCP, ISO), while meeting local food standards, based on the Codex Alimentarius as well as specific conditions prior to fortification, as mentioned above. This part of the food testing allows also to detect hazardous contaminations of the food, such as the growth of dangerous aflatoxin-producing molds due to moist and hot product storage conditions at production sites, as well as during transit to markets, and at the market level.

Production of Fortified Foods

The production of fortified foods or the fortification process of foods takes place in industrial settings that must meet the latest production quality requirements (GMP, ISO, HACCP, etc.), be third-party certified, and have an active Food Safety Management System (FSMS). Medium- to large-scale producers are generally better-resourced to meet such requirements while small-scale producers would struggle. The way the food is fortified, the forms of the chosen fortificants and their inclusion levels are based on the public health response to the micronutrient needs of the population and tailored to the food vehicle matrix. The interaction of fortified foods with other foods consumed in the local diet as well as the interaction of the micronutrients within the food itself with the overall diet are important to consider. The average daily intake of the food to be fortified further influences the level of fortification. International recommendations on food fortification exist based on such analyses and should therefore be followed as a starting point before tailoring fortification to local circumstances.

a. Food matrix
Before choosing the food fortificant, knowledge about the local diet is necessary. This includes understanding what the overall diet consists of. For example, diets high in carbohydrates are also high in phytase, which inhibit the absorption of iron; therefore, in countries where the local diet is high in carbohydrates, a high potency, bioavailable iron fortificant is needed for fortification. Added nutrients can adversely interact with the food vehicle matrix due to the pro-oxidant and catalytic properties of many of the essential minerals and the susceptibility of many vitamins to destruction by heat, light and oxygen. Such technical problems have been overcome through advances in food science and food technology across an increasingly wide range of applications.

b. Fortificant choice and level
This refers to what levels of fortificants and what type of fortificants are chosen to put into a food. Specific consideration needs to be given to avoiding organoleptic and sensory changes to foods after fortification. If the international recommendation on how to fortify foods and at what levels of fortificant are followed, there are no organoleptic changes to be expected. Nonetheless, certain fortificants need special attention as, if sub-optimally added and mixed with other nutrients, they can lead to such changes; these include NaFeEDTA, vitamin B2, vitamin C and DHA. The food matrix itself influences the bioavailability of fortificants, particularly iron. Because of the high nutritional importance of iron in food fortification – along with large differences in its bioavailability, cost and stability – the types, sources and levels of iron in premixes need special consideration and control. In partnering with an ingredient supplier for the premix, the supplier would typically work out options for an optimal formulation that meets these considerations.

c. Processing
The fortification is done while the different foods are processed. Examples are:

i. Grains
Wheat and maize are milled into flour and, during the milling process, the premix is added. All other types of grains are fortified in the same way that the premix is added during the milling process. Simple micro-dosing feeder equipment is needed and usually placed on top of the final flour collection conveyor. It is critical that the feeders are placed at least 3 m from the end of the discharge conveyor. This is to ensure proper mixing of the premix into the flour as it is being milled. The feeder must be calibrated to determine the rate of premix discharge in grams per minute. This is carried out by weighing the amount of premix that is being discharged in grams per minute at different speed settings of the feeder. Control mechanisms are built in to ensure that if the flour mill stops the feeder will stop too or alerting if the feeder runs out of premix, etc.

ii. Grains
Rice is eaten in grain (rice kernel) form and in flour form (e.g. vermicelli, crackers). The fortification of rice kernels is done with specific production methods but the most common and suitable to all types of different cooking methods is the extrusion method. In this method, rice grains and broken rice are milled into flour and, with the addition of water and the fortificant premix, is prepared into a dough, which is run through an extruder (similar to a pasta machine) to form fortified rice kernels that simulate regular rice kernels. The fortified rice kernels are then blended into non-fortified rice in specific ratios. The fortification of rice flour is the same as fortifying wheat flour, which means the premix is added during the milling process via a feeder.

iii. **Liquids**
Milk, oil, fish/soy sauce fortification is done in similar ways as the premix (which is prepared to blend easily with the food vehicle) is simply added by stirring the premix into the liquid. For milk, the premix is added before pasteurization and Ultra-High Temperature (UHT) treatment. For oil, the premix is added into oil conforming to specific chemical requirements, and mixed at a specific temperature in vertical tanks with turbines or propeller agitators to allow optimal homogenization of the premix with the oil. Premix for fish- and soy sauce is simply added into the food tank and thoroughly stirred; for optimal results, this process should be motor-driven.

iv. **Condiments**
Salt, sugar and bouillon cubes: Premix is added at the last moment after the salt has been produced; the same applies to sugar. Both foods need to have the highest quality standard in terms of purity as impurities can influence the color after fortification. For salt, the commonly-used fortificant form of iodine is potassium iodate (KIO3), a more potent and stable form but also more expensive than the alternative, potassium iodide (KI), which can react with sensitive vitamins. While its stability means KIO3 is the preferred form in tropical climes, producers in temperate-climate countries may also use KI as it is cheaper and less likely to react with sensitive vitamins in cooler temperatures. Bouillon cubes are manufactured in a way that the ingredients are pressed together in the form of a cube. Premix is added in dry form to the bouillon cube and then pressed together into a cube. If the iron fortificant in bouillon cubes is NaFeEDTA and the bouillon cube also contains some herbs, attention needs to be given as NaFeEDTA can interact with these food ingredients and alter the color of the bouillon cube.

v. **Processed cereal products**
E.g. bread, biscuits, noodles: These food products are fortified by using fortified flour.

vi. **Fortificants used in foods**
Oils (vitamins A, D and E [added as a nutrient or antioxidant]); liquid, skimmed milk (vitamins A and D mainly; vitamins C and E and calcium are possible but implementation has been limited); sugar (vitamin A); salt (iodine; iron and folic acid has been implemented at limited scale, not for public health purposes); wheat flour (WHO recommends vitamins A and B12, folic acid, iron and zinc; more recently, vitamin D, but implementation has been limited); corn flour (same as for wheat flour); processed foods, such as noodles and bread (same as for wheat flour; additionally, iodized salt is used in bread production in some countries); bouillon cubes (iron [in different forms and some forms are patented], vitamin A, sometimes zinc and iodine [by using iodized salt in the production of bouillon cubes].

vii. **Equipment**
In general, food fortification does not require sophisticated or specialized equipment, except in the case of producing fortified rice kernels. In most cases, the existing production line requires minimal adaptation to accommodate the addition of micronutrient premixes at the relevant stage of processing. For example, the same dosing equipment already in use to add substances such as stabilizers or food additives during the production of wheat flour can be used for adding a micronutrient premix as well. There are more sophisticated dosing mechanisms than others and this depends on what the company is using, e.g. feeders using different types of discharge mechanisms (i.e. roller, disc, screw) or feeders equipped with load cells that allow for automatic weight measurement of the premix going into the flour stream. The same applies to oil and fish/soy sauce fortification in that existing equipment can be adapted for use in the fortification process. For example, premix is added into existing oil or fish/soy sauce tanks which have a motor-agitated stirring mechanism to allow for optimal distribution of the premix in the oil/sauce. Even milk, butter/ghee, yogurt and margarine fortification can be done with existing equipment as the premix is added to existing production equipment. Salt and sugar need specific spraying and mixing machines but these are part of the production process. What is important is that food/beverage manufacturers who want to fortify their products need to partner with an ingredient supplier that can formulate and tailor fortificant premixes for optimal incorporation, bioavailability, cost and addition to the manufacturer's existing production processes.

d. **Testing**
This refers to conducting quality control tests during and after the process of production of fortified foods to guarantee that the food has been fortified according to international and local standards as well as to manufacturing standards such as GMP, ISO, HACCP, etc. There are several means to test if a food has been adequately fortified, ranging from qualitative tests (is the fortificant present) to quantitative tests (is the fortificant in the required level present). For example, during the milling process, the presence of the added premix to the flour is an essential test. The Iron Spot Test IST (American Association of Cereal Chemistry Official Method) can be used to detect the presence of iron in the fortified flour. The test involves a chemical reaction between the added iron and the thiocyanate ion in an acid and hydrogen peroxide. Red dots on the flour sample indicates the presence of added iron. The added iron only comes from the premix and no other source. Spot tests are also used for determinations of iodine in salt. Other quantitative tests that are looking at how much premix is present in fortified foods are more sophisticated and use different methods ranging from HPLCs, Colorimetric, Spectrophotometric or Titration Methods depending on the type of premix and food. Rapid and easy transportable toolkits for testing the presence and the quantity of premix in fortified foods are also available. Recommendations and guidelines on the use of these tests are available and should be followed.

e. Packaging

This refers to how the fortified food is packaged. In order to maximize the impact of fortified foods on improving micronutrient status, the stability of the micronutrients that are added to the food in the form of the premix is of utmost importance. There are certain factors that influence the stability of micronutrients and these include heat, light exposure, humidity, chemical form of the food itself (acid, alkaline values, oxidizing agents, etc.) and others. To minimize the loss of stability, packaging is one important element and should be done properly as with optimal packaging the fortified food has a longer shelf life and micronutrients are not lost during long transportation or storage under hot and humid conditions. It can also happen that the fortified food is provided in bulk and another company packages the fortified food in the respective package sizes. It is important to shorten the time after fortification and final packaging. The choice of packaging needs to be chosen in line with the food and fortification. For example, vitamin A fortified oil is mainly packaged in plastic bottles, yet, glass bottles would be more suitable as glass is not permeable to oxygen which can quickly degrade vitamin A. Since glass bottles are fragile and more expensive, plastic bottles are used; however, an appropriate plastic coating is needed to prevent oxygen passing through the bottle or, most frequently practiced, a certain overage of the fortificant would be added to compensate for a certain loss of vitamin A due to oxygen degradation.

Distribution

Once the fortified food is produced, it is important to understand how the fortified food is distributed and how long it takes until final consumption. Micronutrients are sensitive to physical and chemical factors and can lose their nutritional value by degrading due to oxidizing, being in acidic and alkaline environments, light exposure, moisture and other factors along the food fortification value chain.

Due to advances in food science and technology, food processing has advanced to optimize the stability of micronutrients in foods; hence, shelf life has been increased for both foods naturally high in vitamins and minerals as well as for fortified foods. Nevertheless, storage and transportation of fortified foods can negatively influence the stability of micronutrients if not properly done and in line with premix ingredients suppliers' guidelines.

a. Storage

Storage conditions are a key component along the food fortification value chain. Minerals are more stable than vitamins but they change when they are exposed to heat, air or light. Some minerals are also more sensitive to moisture such as zinc, iron and copper. There are two levels of concern: 1. one is the level on how the premix is stored before used for fortification and 2. how fortified foods are stored until they reach the consumer. 1. Accredited premix suppliers specify that premix packages need to be stored at room temperature, in non-humid and dark storage places. These recommendations need to be followed for optimal micronutrient stability. 2. Fortified food is either stored in bulk or in smaller size packaged containers. For both, storage conditions need to be the same and storage at room temperature, non-humid and cool place is recommended. Once the fortified food package is opened, specific instructions are given in regard to how quickly the food needs to be consumed.

Storage for commercial purposes needs to be critically reviewed as for certain fortified foods such as fortified milk the exposure in supermarket food shelves under fluorescent or LED lighting is not recommended, yet widely practiced. If fortified foods are exposed in bulk and open containers, (which is still the case in some low-income and middle-income countries and where fortified staple foods are bought in loose and small quantities), the fortified foods need to have a quick turn over as storage under these conditions will negatively influence the stability of the micronutrients in the food.

b. Transportation

Transportation conditions are as important as storage conditions in regard to influencing micronutrient stability and nutrition impact of fortified foods. Long transportation under hot, humid and sub-optimal packaging conditions will reduce stability of micronutrients in fortified foods.

Consumption

A key goal of mass staple food fortification is when the majority of the target population does not perceive any change in the fortified product and there is no need for any change in food habits. In short, consumers receive the benefit of improved nutrition without needing to be persuaded or change their regular consumption practices. If there are 'niche products' that are fortified on an industrial voluntary basis, the consumer will be aware and is knowledgeable about the fortified foods. There are no organoleptic or sensory changes of foods that are fortified as today's technology and knowledge produces fortified foods without any changes compared to unfortified foods. Consumers might however resent fortified foods due to perceptions or pre-emptied opinions fueled by media or extreme attitudes toward processed foods.

a. **Cooking Methods**
Advances in food science and technology have contributed to the fact that micronutrients are much more stable in foods than previously. This applies also to different cooking methods such as frying, baking or boiling at high temperatures and repeatedly. The stability of vitamins and minerals depend in regard to the food vehicle; for example, vitamin A is more stable in flour than in oil and remains stable for longer if containers of fortified foods are closed and properly stored at room temperature.

b. **Testing**
Governments that have implemented mandatory food fortification laws are responsible to test the fortified foods on a regularly basis for its quality and safety. They also have put in place enforcement systems so that industry adheres to government regulations and consumer's health is protected. While enforcement systems and food safety regulations are in place in the western world, these systems are lacking behind in the low- and middle- income countries as financial resources and efficient government systems are lacking.

c. **Overdose and risk of toxicity**
To date, there has been no documented toxicity case related to fortified foods. The international and national guidelines for fortification levels are calculated in such a way that there is no risk of dangerously high levels being reached; it is, in fact, impossible to consume quantities of fortified foods to reach toxic levels of the fortificants. Fortified foods should not be confused with nutritional supplements, which deliver high, concentrated doses of vitamins and minerals.

ALA	Alpha-linolenic acid; a plant-based essential omega-3 polyunsaturated fatty acid
Bioavailability (biological availability)	A term used to describe the proportion of a nutrient in food that is utilized for normal body functions (Encyclopedia of Food Sciences and Nutrition, Second Edition, 2003). In food fortification, bioavailability can be defined as the proportion of the administered substance capable of being absorbed and available for use or storage by the body.
Biofortification	Biofortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. (WHO, 2016)
Codex Alimentarius	The Codex Alimentarius (Latin for "Food Code") is a collection of internationally recognized standards, codes of practice, guidelines, and other recommendations relating to foods, food production, and food safety. (http://www.fao.org/fao-who-codexalimentarius/en/)
CSB	Corn soy blend; CSBs are a type of fortified blended food (blends of partially precooked and milled cereals, soya, beans, pulses fortified with micronutrients) used by humanitarian agencies, such as the World Food Programme in supplementary feeding or food assistance programs as protein supplements and to prevent and address nutritional deficiencies. Special formulations may contain vegetable oil or milk powder. To be practical for use in emergencies, CSBs and other fortified blended foods are usually prepared by mixing the product with water and cooking it as a porridge.
DHA	Docosahexaenoic acid (DHA) is an omega-3 fatty acid that is a primary structural component of the human brain, cerebral cortex, skin, and retina. It can be synthesized from ALA or obtained directly from breast milk, fish oil or algae oil.
Encapsulation / microencapsulation	Small particles of a functional ingredient packaged in a minute capsule for inclusion in a food.
Enrichment	Addition of nutrients to food to replace nutrients that are lost during food processing.
EU/EC	European Union/European Commission
Extrusion (for producing fortified rice kernels)	Forcing a viscous solution through a spinneret-like machine (similar to a shower head), extrusion produces fortified rice kernels by pushing a dough made from rice flour (e.g. from broken rice kernels) mixed with the fortificant premix into a barrel and, in the case of hot extrusion, cooking the product under pressure and at high temperature and then extruding.
FAO	Food and Agriculture Organization of the UN
FBF	Fortified blended food; see CSB, above.
FFI	Food Fortification Initiative
Food and nutrition security	Food and nutrition security exists when all people, at all times, have physical, social and economic access to food which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is support by an environment of adequate sanitation, health services and care, allowing for a healthy and active life (Committee on World Food Security, 2012).

Food fortification	Food Fortification is the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements) in a food, so as to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health.
Food matrix	The nutrient and non-nutrient components of foods and their molecular relationships, i.e. chemical bonds, to each other. The food matrix is especially important to consider in food fortification as food products are usually eaten in combination with other food products during a meal. A food product has a physically and nutritionally complex structure that has influence on its digestion and the absorption of the nutrients by the body. The effects of the structure of a food product are also defined as matrix effects. Matrix effects can also change the bioactive properties of nutrients.
GMP	Good Manufacturing Practice; a system for ensuring that products are consistently produced and controlled according to quality standards set by agencies that control the authorization and licensing of the manufacture and sale of food and beverages, cosmetics, pharmaceutical products, dietary supplements, and medical devices.
HACCP	Hazard Analysis and Critical Control Points; a system that identifies potential biological, chemical and physical hazards in food production and establishes preventative measures for their control.
HPLC	High-performance liquid chromatography; a technique in analytical chemistry used to separate, identify, and quantify each component in a mixture.
HTST	High Temperature/Short Time; also known as 'flash pasteurization,' HTST is a process by which food is sterilized at very high temperatures but only for a very short period. This is applied to perishable beverages like fruit and vegetable juices, and some dairy products such as milk.
Iodization	Iodization is the process of fortifying salt for human consumption with iodine and is an effective strategy to increase iodine intake at the population level.
ISO	International Standards Organization
IST	Iron Spot Test; The iron spot test (IST) is a qualitative technique for detecting the presence or absence of added iron in flour. With the exception of sodium ferric ethylenediaminetetraacetate (NaFeEDTA), the IST detects all forms of iron currently used in fortification programs]. Because of its simplicity and low cost, the IST is commonly used at mills for quality control to ensure that iron, and thus the micronutrient premix, has been added to flour.
KOH/g	Acid value; In chemistry, the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance.
Micronutrients	Nutrients such as vitamins and minerals, which are required in relatively small quantities to ensure good health. These include: • Vitamin A (Retinol, retinal, retinyl esters, and retinoic acid; carotenoids, e.g. beta-carotene, which can easily be converted to vitamin A as needed) • Vitamin B1 (Thiamin) • Vitamin B2 (Riboflavin) • Vitamin B (Niacin) • Vitamin B5 (Pantothenic acid) • Vitamin B6 (Pyridoxine) • Vitamin B12 (Cobalamin) • Vitamin C (Ascorbic acid) • Vitamin D (Calciferol) • Vitamin E (Alpha-tocopherol) • Vitamin B9 (Folic acid, folate) • Calcium

Micronutrients (Continued)	• Fluoride • Iodine • Iron • Potassium • Selenium • Sodium • Zinc
Organoleptic (changes)	Organoleptic properties are the aspects of food, water or other substances that an individual experiences via the senses—including taste, sight, smell, and touch. Food processing brings about changes in organoleptic and physicochemical qualities as well as nutritional values.
Overage	To make correct claims about the nutrient content of a product on its label, the amount of the added nutrient should actually be more than that amount stated or declared on the label. The difference between the formulated and the declared levels is known as overage. Overages vary according to the inherent stability of the nutrients, the conditions under which the food is prepared and packaged, and the anticipated shelf life of the product. Thus, the more unstable/sensitive nutrients, such as vitamin A, generally require high overages.
Oxidation	An irreversible process by which molecular oxygen combines with nutrients in food, a process which decreases the quality of the food by creating rancidity. It occurs in peeled fruits and vegetables, such as bananas, apples and potatoes, as well as fats and oils.
Pasteurization	Process designed to reduce the population of pathogenic bacteria in a product, sufficient to ensure product safety but with modest impact on the nutritional properties and flavor of the product. Traditionally, this term has been applied to thermal processes but it can also refer to emergent alternative technologies with the purpose of pathogens inactivation.
PDCAAS	Protein digestibility-corrected amino acid score
pH value	Scale used to express acidity or alkalinity, from 1 (strong acid) through 7 (neutral) to 14 (strong alkali); pH value is a measure of the acid/base properties of a substance.
Protein/amino acids	Complex, nitrogen-containing substance that is found in food and is essential for the functioning of the human body. Protein molecules consist of long chains of building blocks called amino acids. Some of these amino acids can be manufactured in the human body. Others must be supplied by the diet. The body breaks down food proteins into their amino acid constituents and then reassembles the amino acids into the proteins needed for normal functioning.
Premix, fortificant	A fortificant premix is a blend of micronutrients (vitamins and/or minerals) and other ingredients (e.g. antioxidants, additives, stabilizers) formulated specifically to fortify a particular food or beverage product. Combining these ingredients in a premix simplifies the addition of the fortificants to the food or beverage during production, and improves accuracy in the mixing and distribution of these micronutrients throughout the food or beverage. Without using a premix, food/beverage manufacturers would need to procure straight vitamin and/or mineral ingredients (referred to as 'straights' by ingredient suppliers) separately from suppliers, develop the optimal formulation on their own and ensure the correct ratio of ingredients are added to the food or beverage during processing.
PV	Peroxide Value; measures the amount of peroxides and hydroperoxides in a sample of fat produced in the oxidation process.

QA/QC	Quality Assurance/Quality Control; all the planned and systematic activities implemented within the quality system that controls each stage of food production from raw material harvest to final consumption, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality and ensure that a uniform quality food is produced.
Rancidity	The spoilage and decomposition of fats, fatty acids and oils through exposure to oxygen. Causes an unpleasant odor and flavor in food.
RDI	Reference Dietary Intake. Nutrient intakes recommended by the Food and Nutrition Board of the National Academy of Sciences for healthy people in the United States are referred to as Recommended Dietary Allowances (RDAs) and are established for different age groups and genders. On nutrition labeling of packaged foods, however, an RDI is selected from among the RDAs for all the various age and gender groups (usually the highest RDA), which is the basis for the percent Daily Value (DV) that is included in the label for the listed nutrient.
RTD/RTE	Ready-to-drink/ready-to-eat; food or beverage in a form that is consumable without additional preparation (e.g. washing or cooking of the food) by the food establishment or consumer, and that is reasonably expected to be consumed in that form.
Stability	Relative resistance of a product to an undesirable breakdown or change. For fats and oils, stability may refer to resistance to oxidation, hydrolysis, flavor reversion and formation of off odors and flavors.
SUN	Scaling Up Nutrition; a collaborative process that began in 2009 with the development of the Scaling Up Nutrition Framework and evolved into a Movement supported by governments, development organizations and the private sector. SUN is a global push for action and investment to improve maternal and child nutrition. Improving nutrition is a precondition to achieving goals of eradicating poverty and hunger, reducing child mortality, improving maternal health and combating disease – which all contribute to a stronger future for communities and nations.
UN	United Nations
UNICEF	United Nations Children's Fund
USI	Universal Salt Iodization; USI is the main strategy to eliminate iodine deficiency. Over the past two decades, national salt iodization programs have been introduced and scaled up in many countries. The basic concept of USI implies that all edible salt (household, processed food and animal salt) should be iodized.
WFP	World Food Programme
WHO	World Health Organization

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