International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

Review Article

Food Fortification to Combat Micronutrient Deficiencies and Its Impact on Sustainable Development Goals

Lovedeep Nagar[1], Harvinder Popli[2], Aayushi Gupta[1], Manish Ruhela[1]

[1]Research Scholar, [2]Professor,
Delhi Pharmaceutical Sciences and Research University, Pushp Vihar, Sector-3, M.B Road, New Delhi -110017

Corresponding Author: Lovedeep Nagar

ABSTRACT

Micronutrients are essential for the growth, brain and body development and for immunity against the diseases in minute quantities and include vitamins and minerals. These are provided by diet and external sources as the body cannot synthesize them. Micronutrient deficiency is a global health issue with malnutrition resulting in poor physical and mental development, mental retardation and blindness in the vulnerable population including young children, pregnant and lactating women and elderly. One third to half of the global population is affected by micronutrient deficiency affecting society in terms of unrealized potential and economic productivity loss. Food fortification is a safe and effective tool that improves intake of micronutrients and restores the amount lost during processing by providing key nutrients in food. The micronutrient deficiencies affect the sustainable development goals. The technological and regulatory factors govern the choice of any combination of food and food vehicle. The vast range of foods are used for fortification and some of them are cereals and cereal-based products, milk and dairy products, tea, fats and oils, beverages and the condiments such as salt, sugar and soy sauce. The fortification vehicles used in foods differ from country to country. For sustainable over the long term, the food processors require an effective program for monitoring compliance. The educational program creates awareness and helps people to teach about the benefits of food fortification.

Keyword: Food fortification, deficiencies, micronutrients, sustainable development goals, regulatory.

INTRODUCTION

According to the estimates of the World Health Organisation more than 2 billion people have deficiencies of key vitamins and nutrients, particularly vitamin A, iodine, iron and zinc. [1] The pregnant and lactating women and young children are found to be the most vulnerable groups affected to micronutrient deficiencies. The majority of populations affected are from developed countries where micronutrient deficiencies coexist. [2-4] The strategy that prevents vitamin and mineral deficiencies and can be used safely and effectively includes food fortification. To reduce specific nutrient deficiencies, the medium-to long-term solution is food fortification in a population. [5]

According to WHO estimates, 190 million preschool children and 19.1 million pregnant women globally were vitamin A deficient (have serum retinol <0.70 µmol/l), [4] over 100 million women of reproductive age have deficiency of iodine [6] and also 82% of pregnant women over the world do not have adequate zinc intakes to meet normal pregnancy needs. [7] Iron deficiency was widespread and 1.62 billion people globally were anemic, with apical pervasiveness among preschool children (47%) leaded by pregnant women (42%). [8] Substandard status of vitamin B6 and B12

were seen in developing countries. [9] The mortality data of WHO demonstrated due to iron deficiency 0.8 million deaths attributed each year and similar rate of deaths was seen due to vitamin A deficiency. Food fortification helps in eliminating nutritional deficiencies like goitre, rickets, beriberi and pellagra. The emergent deficiencies like folate leads to neural tube defects, zinc affects child growth and selenium causes cancer. [5] Effects are not only limited to health parameters but affected the economies through physical and mental disabilities altering work productivity. [10]

The wheat and wheat products, corn, rice, milk and milk products, salt, sugar, cooling oils, condiments and breakfast cereals are the most widely used food vehicles for fortification. They offer channels for delivery of micronutrients and are within the reach of market in developing countries. [11]

HISTORY

The nutrient addition to staple foods is not a novel concept and was prevalent in Europe and North America for over 70 years ago to deal with micronutrient deficiencies. [11]

In the early 1920 century, iodization of salt began in Switzerland [12] and United States of America, [13] Denmark introduced vitamin A-fortified margarine in 1918, and vitamin A-fortified milk and iron and B complex flour introduced in the 1930s in developed countries. [5] In the United States in 1932, milk fortification with vitamin D was done due to the occurrence of rickets in children. Further, in 1941, bread and flour were fortified with B vitamins. [5] In 1992, U.S. Public Health Service recommended all pregnant women must consume 400 µg of folic acid daily in addition to natural uptake of folates from food to prevent neural tube defects. [14] In 1998, Institute of Medicine (IOM) recommended daily uptake of 400 µg of folic acid either from fortified food or supplements with a daily intake of a normal diet for pregnant women. [15] These recommendations were strengthened by U.S. Preventive Service Task Force and published updated guidelines in 2009. [16] India has focused on addressing the deficiencies of iodine, vitamin A and iron since historically. The vanaspati was fortified since 1953 with vitamin A and mandatory fortification of salt with iodine was done since 1962. [17]

These strategies were universal in developed countries and were deployed by many middle-income countries. The nutrient deficiencies in industrialized countries have been eradicated with rich diet and consumption of fortified foods like juices, salt, flour, margarine, sugar and milk. [11]

FOOD FORTIFICATION

Food fortification, restoration and enrichment are considered as similar terms. According to WHO, food fortification is the assimilation of one or more ingredients to food, whether present in the food or not, for preventing or improving a known deficiency associated with one or more ingredients in the population or in specific groups of the population. Restoration is the addition of a food nutrient which may be lost during the process of Good Manufacturing Process (GMP) or storage and handling procedures. Enrichment is the restoration of vitamin and minerals which are lost during the processing and is substitutable with the fortification. [18]

In food fortification, the commonly eaten and centrally processed foods are identified to ensure fortification during food production and distribution systems. The condiments and staple foods are consumed by a greater section of the population and therefore are choice for fortification. The food vehicle choice is limited to staple foods and condiments in developing countries and includes cereals, fats and oils, salt, sugars and sauces. For fortification, vitamin A, D, iodine, iron, folic acid, zinc and B-complex vitamins are the vitamins and mineral that can be used. [11]

Fortification of food vehicles as per WHO occurs in three major approaches: mass, targeted and market driven. [5] The

widely consumed foods by population such as wheat, milled cereals, salt, oils and fats and sugar are involved in mass fortification [5] to overcome unacceptable public health risk of becoming deficient in particular micronutrients. The fortification of staple foods is cost-effective on a massive scale. The fortification of few expensive staple foods leads to broader micronutrients dissemination throughout the population, especially to poor. The foods consumed by specific population sub-groups such as infants leading to increase intake for that specific group are included in targeted fortification. The complementary foods for young children are approached in targeted fortification. For market-driven fortification, the food manufacturer fortifies some of the products as value-added products and conforms to specifications for acceptable nutrients and quantities. The mass and targeted fortification has focus on micronutrients that are required by most of the population. [19] The food vehicles widely used are grouped into three categories: staples (wheat, oils, and rice), condiments (salt, soy sauce, sugar) and finally the processed commercial foods (noodles, infants complementary foods, dairy products). [5]

Vitamin A, the fat-soluble vitamin is important for immune system and for vision and is added to staple foods such as rice, cereal grains and oils (Figure 1). Fortification of vitamin A helps to avoid vitamin A deficiency, which can cause visual impairment and increased susceptibility to illness. [18]

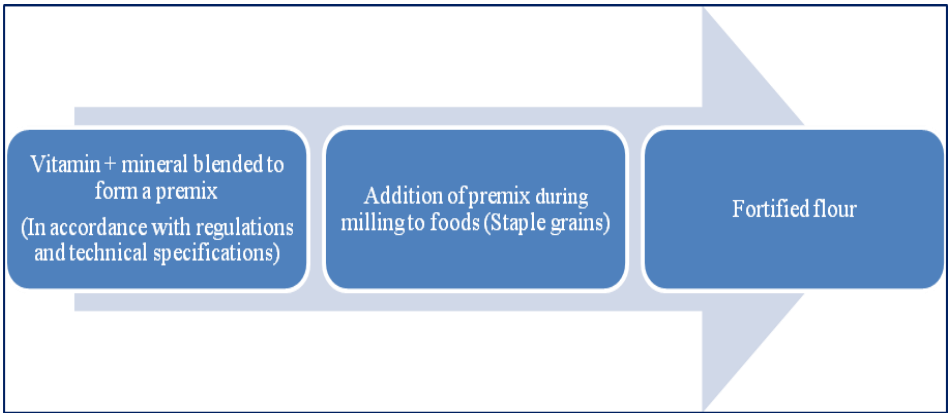

Figure 1- Diagram showing cereal flour fortification

The fortification of wheat and maize flour and rice is done to prevent the nutritional anaemia, birth defects of brain and spine enhance productivity leading to economic progress. Figure 2 depicts the effects of wheat, flour and maize fortification. [20]

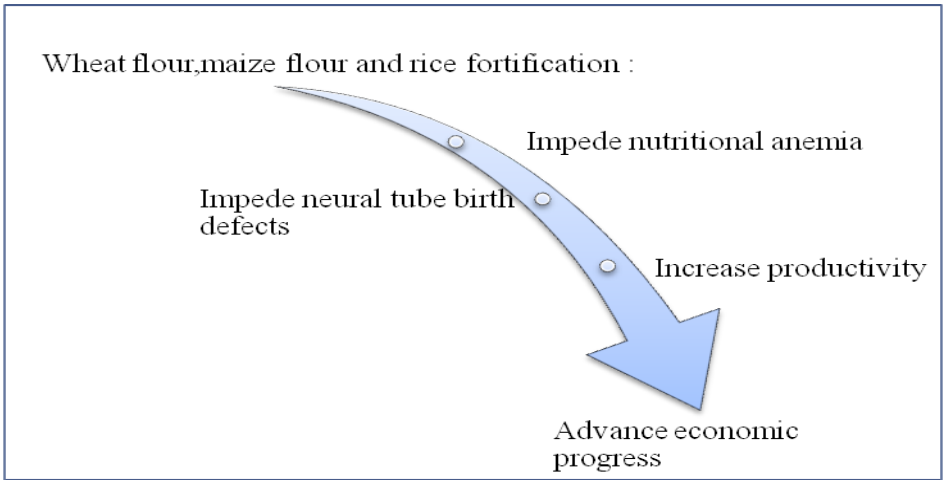

Figure 2- Effects of wheat, rice and maize fortification

Table 1- Role of vitamins and minerals used in flour and rice fortification includes: [20]

Micronutrients	Functions
Folic acid (vitamin B9)	Reduces neural tube birth defects
Zinc	Strengthens immune system
Niacin (vitamin B3)	Prevents Pellagra, a skin disease
Riboflavin (vitamin B2)	Boosts carbohydrates, proteins and fats metabolism
Thiamine (vitamin B1)	Prevents beriberi, a nervous system disease
Vitamin B12	Enables functioning of the brain and nervous system
Vitamin D	Improves bone health by allowing absorption of calcium
Vitamin A	Childhood blindness and lowers the ability of individual's to tackle infections
Calcium	Makes bones stronger, helps nerve muscles to transmit messages, functioning of muscles and blood clotting
Selenium	Helps in thyroid gland functioning and reproduction
Vitamin B6	Metabolism involving enzyme reactions

Food fortification is an attentive public health strategy with the benefit of reaching larger at-risk population groups over existing food delivery systems, without compelling major changes in current consumption patterns. It is a cost-effective way to improve population's nutrient uptake and fortified foods have the advantage of preserving steady body stores. [10]

IMPORTANCE OF FOOD FORTIFICATION

Staple foods that are produced within a particular region can lack particular nutrients due to reasons such as soil region or inherent adequacy from a normal diet. Further addition of micronutrients to condiments and staples can prevent deficiency of diseases on large scale. [18]

The original purpose of food fortification is to decrease the nutritional deficiencies occurrence, specifically which lacks access to essential nutrients in sufficient amounts. People living in developed countries, like Europe, U.S., as well as those living in underdeveloped countries, where a variety of foods are not available, get benefits of food fortification. Another advantage is food fortification results in the elimination of expense of transporting perishable foods, such as vegetables and fruits, meats and dairy products to remote areas around the world. Food fortification results have been extreme, where many nutrition-related deficiencies been eradicated either diminished. [21] Although the extensive accession of nutrients to food and fresh produce fortification is not allowed. The fortification of meat, poultry and fish products is also not allowed by the government of US and European countries which also prohibits the fortification of unprocessed foods. [18]

According to British Nutrition Foundation, around 50 percent of adults in the UK are lacking vitamin D. Deficiency of vitamin D is a choice of concern, as disease rickets returned to the UK in current years. [22] The sufficient levels of vitamin D are not obtained through foods and most people are not exposed to sunlight and result in the high occurrence of vitamin D deficiency in many countries. The foods that are fortified with vitamin D are yoghurt, bread, pasta and juice. The fortified foods increase the levels of serum vitamin D and 25-hydroxyvitamin D and similar bioavailability of vitamin D is obtained from fortified foods and pharmaceutical preparations. [23] Marks & Spencer added Vitamin D and Omega 3 to the bread they packed in the response of concerned customers facing challenges to meet daily dietary amount. [22]

Fortification offers mostly eaten foods more nutritious instead of forcing consumers to change their habits and this makes it successful. [20]

Table 2- Micronutrient deficiencies with disorders and their prevalence around the world [5]

Micronutrient	Deficiency Pervasiveness	Major Deficiency Disorders	Fortifying vehicle
Iodine	2 billion at risk	Goiter, hypothyroidism, iodine deficiency disorders, increased risk of stillbirth, birth defects infant mortality, cognitive impairment	Salt, bread
Iron	2 billion	Iron deficiency, anaemia, reduced learning and work capacity, increased maternal and infant mortality, low birth weight	Wheat and corn flours, bread, pasta, rice, salt, infant formulas and cookies
Zinc	Largely estimated in the developing countries	Poor pregnancy outcome, impaired growth(Stunting), genetic disorders, decreased resistance to infectious disease	Breakfast cereals, infant formulas, cookies and diet beverages
Vitamin A	254 million preschool children	Night blindness, xerophthalmia, increased risk of mortality in children and pregnant women	Milk, margarine, yoghurts, soft cheese, sugar, monosodium glutamate and tea
Folate (Vitamin B9)	Insufficient data	Megaloblastic anaemia, neural tube and other birth defects, heart disease, stroke, impaired cognitive function, depression	Wheat and corn flours, bread, pasta, rice, cookies and infant formulas
Cobolamine (Vitamin B12)	Insufficient data	Megaloblastic anaemia (associated with Helicobacter pylori-induced gastric atrophy)	Breakfast cereals, diet beverages, Wheat and corn flours, bread, pasta, rice
Thiamine (VitaminB1)	Insufficient data, estimated as in developing countries and in famines, displaced persons	Beriberi (cardiac and neurologic), Wernicke's and Korsakov syndromes (alcoholic confusion and paralysis)	Wheat and corn flours, bread, pasta, rice, infant formulas and cookies, breakfast cereals, vegetable mixtures and amino acids
Riboflavin (Vitamin B2)	Insufficient data, estimated as in developing countries	Non-specific-fatigue, eye changes, dermatitis, brain dysfunction, impaired iron absorption	Wheat and corn flours, bread, pasta, rice, vegetable mixtures and amino acids, breakfast cereals and infant formulas and cookies
Niacin (Vitamin B3)	Insufficient data, estimated as in developing countries and in famines, displaced persons	Pellagra (dermatitis, diarrhoea, dementia, death)	Wheat and corn flours, bread, pasta, rice, breakfast cereals, cookies and infant formulas
Vitamin B6	Insufficient data, estimated as in developing countries and in famines, displaced persons	Dermatitis, neurological disorders, convulsions, anaemia, elevated plasma homocysteine	Wheat and corn flours, bread, pasta, rice, infant formulas, cookies and breakfast cereals
Vitamin C	Common in famines, displaced person	Scurvy (fatigue, hemorrhages, low resistance to infection, anaemia)	Diet beverages, juices and substitute drinks
Vitamin D	Extensive in all age groups, low exposure to ultraviolet rays of the sun	Rickets, osteomalacia, osteoporosis, colorectal cancer	Milk, margarine, yoghurts, soft cheese
Calcium	Insufficient data, estimated to be widespread	Decreased bone mineralization, rickets, osteoporosis	Soy milk, breakfast cereals, infant formulas and cookies, juices, diet beverages and substitute drinks
Selenium	Insufficient data, common in Asia, Scandinavia, Siberia	Cardiomyopathy, increased cancer and cardiovascular risk, osteoarthropathy	Milk, pasta, corn and wheat flours, breakfast cereals, infant formulas and cookies, juices and spreads
Fluoride	Widespread	Increased dental decay risk	Infant formulas and cookies, breakfast cereals, wheat and rice flour, milk, juices

(Source: Adapted from Allen L et al. [5])

MICRONUTRIENT DEFICIENCIES IN VULNERABLE GROUPS- CHILDREN, WOMEN AND ELDERLY

Micronutrient deficiencies have been outspread among 2 billion people in both developed and developing countries affecting people of all genders and ages. [5] The one third of two billion people suffering from micronutrient deficiencies is from India and this hidden hunger affects rich and poor, urban and rural, old and young –with children and women are at most risk. [17] They also act as aggravating factors in infectious and chronic diseases, influencing morbidity, mortality and quality of life. [5]

In India, over 70% populations consume less than half of RDA of micronutrients. [17] The largest proportion of underweight children among the world is in India, almost double as compared to Sub-Saharan Africa. [24] The iron deficiency affects 273.2 million children (0-59 months), Vitamin A deficiency affects 190 million pre-school children and the risk of iodine deficiency disorders affects more than 35 million newborns. [25-27] In USA, the

3.1% of pre-school children's have anaemia which is 58.4% in India. [17]

Micronutrient deficiency has been responsible for a broad range of non-specific physiological impairment, thereby leading to decreased resistance to infections, metabolic disorders and impaired physical and psychomotor development. [19] Globally, the vitamin A deficiency was seen in 21% of children and suffered from increased death rates of diarrhoea, measles and malaria. The vitamin A deficiency resulted in about 800,000 deaths in children and pregnant women and had 1.8% eye disease effects globally. Zinc deficiency contributed to death of about 800,000 children. [28] As per reports of UNICEF, around 330,000 child deaths annually are precipitated in India by Vitamin A deficiency. [29]

Iron Deficiency- Deficiency of iron causes anaemia and the symptoms are pale inner eyelids, nailbeds, gums, tongue, lips and skin. Other symptoms are tiredness, headaches and breathlessness. The pregnant women and young children found to be at great risk. Iron deficiency can cause early neonatal mortality and maternal mortality. [19]

Iodine deficiency- Iodine deficiency leads to goitre and cretinism. Stunted physical and mental growth is also seen with symptoms including mental deficiency, deaf-mutism, ataxia, dwarfism and hypothyroidism. The goitre can be prevented by proper intake of iodine. [19]

Iodine is needed for synthesis of thyroid hormones and plays major role in cell replication. Iodine deficiency during gestation leads to abortions, congenital anomalies, stillbirth, low birth weight, cretinism, psychomotor defects and increased neonatal mortality. [19] Both selenium and iodine are involved in normal functioning of thyroid gland and their inadequacy would lead to hypothyroid cretinism [31]

Vitamin A deficiency- Vitamin A is vital micronutrient for normal visual system functioning, growth and development, epithelial cellular integrity maintenance and immune functioning and reproduction. [30] Deficiency of vitamin A leads to xerophthalmia, [19] blindness, reduced immunity, growth impairment and greater susceptibility to infectious diseases. [29] Globally 21% children have vitamin A deficiency and suffer increased death rates from diarrhoea, malaria and measles. [19]

Zinc deficiency- Zinc deficiency is more prevalent among children in developing countries where diets are high in phytates and low in animal products. Diarrhoea worsens due to intestinal loss during zinc deficiency. Low activity and depressed motor development is seen in vulnerable children. [31] Zinc deficiency results in 800,000 children death each year. [28] Zinc fortification resulted in children with improved growth and reduced child mortality and lower rates of diarrhoea, malaria and pneumonia. [31]

Selenium deficiency- Selenium deficiency has been observed in China, Tibet, Russian Federation and the New Zealand. Thyroid injury and decreased production of thyroid hormone is seen due to selenium deficiency. Keshan's disease, an endemic cardiomyopathy is caused due to selenium deficiency mostly affecting children and pregnant women. [31]

FOOD VEHICLES AND FORTIFYING AGENTS

The common food vehicles adopted for fortification from US Dietary Supplement Fact Sheet from the Office of Dietary Supplements of National Institute of Health and are included in Table 3. [32]

Table 3- Commonly used food vehicles and fortifying agents with rich foods

Food Vehicle	Fortifying Agents	Rich Foods (Natural Sources)
Salt	Iodine, iron	Seaweed including kelp, nori, kombu, arame, cranberries, organic navy beans and yoghurt, liver, meat and fish, legumes such as tofu, lentils and beans, dried fruits such as apricots, prunes and raisins
Wheat and corn flours, bread, pasta, rice	Vitamin B complex, iron, folic acid, vitamin B12	Eggs, wholegrain bread and brown rice, peas, liver, milk, meat and fish, porridge, broccoli, potatoes, soya beans, asparagus, chickpeas, peas, spinach, cheese
Milk, margarine, yoghurt, soft cheese	Vitamins A and D	Fatty fish like herring, tuna, mackerel and salmon, beef liver, cheese, egg yolks, oysters, mushrooms and cow milk
Sugar, monosodium glutamate, tea	Vitamin A	Carrot, sweet potato, lettuce, milk, yoghurt, mango, kale, animal-sourced food such as oily fish, liver, beef and lamb liver, cheese and butter
Infant formulas, cookies	Iron, vitamins B1 and B2, niacin, vitamin K, folic acid, zinc	liver, meat and fish, legumes such as tofu, lentils, lamb, beef, eggs, nuts, oats, oranges, green leafy vegetables such as spinach, turnip, kale, collards, chard, lettuce, Oysters, pumpkin and squash seeds, chickpea, mushroom and broccoli
Vegetable mixtures amino acids and proteins	Vitamins and minerals	lamb, beef, eggs, nuts, oats liver, meat and fish, legumes such as tofu, lentils, vegetables such as spinach, turnip, kale, collards, chard, lettuce, sweet potato, lettuce, milk, yoghurt, egg yolks
Soy milk, orange juice	Calcium	Cheese, yoghurt, sardines and salmon, almonds, collard greens, spinach, kale, turnips, milk, soybeans
Juices and substitute drinks	Vitamin C	Broccoli, Brussels sprouts, cauliflower, cauliflowers, red and green pepper, spinach, cabbage and sweet potato, guava, orange, kale
Breakfast cereals	Vitamins and minerals	Salmon, kale, seaweed, garlic, shellfish including clams and oysters, potatoes, beef liver, sardines, blueberries and egg yolks
Diet beverages	Vitamins and minerals	Milk, lentils, spinach, salmon, kale, seaweed, garlic, shellfish including clams and oysters, potatoes, beef liver, sardines, blueberries and egg yolks

INITIATIVE TO ELIMINATE NUTRIENT DEFICIENCIES

Fortification is supported by organizations like UNICEF, the WHO, the U.S. Centers for Disease Control and Prevention (CDC), the Global Alliance for Improved Nutrition (GAIN) and Nutrition International to eliminate the nutrient deficiencies in vulnerable populations. [33]

In September 2015 the United Nations embraced 17 Sustainable Development Goals (SDGs) and fortification of grain products is the primary step for achieving SDGs. The SDGs can be achieved by reducing deficiencies for vitamins and minerals. Out of 17, grain fortification helps to address eight of SDCs by incorporating iron, zinc, B vitamins including folic acid, niacin, riboflavin, thiamine, B12 and vitamin B6 to rice, wheat and maize flour. [33]

SDG 1- No poverty: The 17% lower productivity is estimated in heavy manual labour and 5% in other manual labour in a population suffering from anaemia. The iron deficiency leads to undeveloped mental capacity in children and affects their academic potential and performance. Further, childhood anaemia results in 2.5% drop in wages in adulthood followed by hampered productivity and economic growth. The deficiency of iron, riboflavin, folic acid, zinc and vitamin B12 contribute to anaemia. These nutrients are added to wheat flour, maize flour and rice, more than 80 countries have made a legislation for it. [33]

SDG 2- Zero hunger: The 45% of deaths among children below 5 years are due to malnutrition. About 2 billion people are affected by stunting, as a risk of stunting increases with vitamin and mineral deficiencies. [33]

The productivity in adults increases upon appropriate intake of nutrients, leading to enhanced agricultural production followed by food supply growth and providing assistance in hunger. [33]

SDG 3-Good Health and well-being: Fortification helps to attain goals of maternal and new-born health, infectious disease and non-communicable diseases. [33]

- Maternal and New-born Health-Folic acid fortification lowers the birth defect, risks of spine and brain. The fortification of wheat flour with folic acid demonstrated the reduced birth defect incidents in meta-analysis at an average of 46%. Infants born in anaemia during pregnancy have low weights with less than 2500 grams or 5.5 pounds and are at a greater risk of death and diseases. There also occurs the greater risk of poor mental development in an

early phase of childhood followed by diabetes and heart disease at a later stage. [33]

- Infectious Disease- Zinc promotes immunity; provide resistance to infections and helps in proper growth and development of nervous system. Deficiency of zinc increase malaria, pneumonia and diarrhoea risk. As per reports of 2012, there seen 17% inadequate zinc intake risk in the global population. The zinc deficiency was responsible for 18% malaria, 16% lower respiratory tract infections and 10% diarrhoea worldwide. [33]
- Non-communicable diseases- Anaemia and diarrhoea are non-communicable diseases. The deficiencies of vitamins and minerals cause nutritional anaemia and addition of iron, riboflavin, folic acid, zinc and vitamin B12 reduces the risk in food during the milling process. The deficiencies of vitamin A and zinc-lead to diarrhoea, along with unsafe water and sanitation as the leading risk factors. [33]

SDG 5-Gender equality: Females are affected by anaemia largely than males. Rates of anaemia remain higher in females by the end of puberty and through reproductive years than in males. Thus, boosting iron intake in females via fortified foods reduces anaemia followed by greater performance and work productivity and helps in attaining gender equality. [33]

SDG 8-Economic Growth- As per the Global Nutrition Report 2017, the low and middle-income countries stated 16:1 benefit to cost ratio in fortifying foods. The fortification with folic acid prevents healthcare expenditures used in the treatment of birth defects of brain and spine. The Spina bifida is incurable and common birth defect often results in paralysis, bowel and bladder control problems. In 2002, according to a study, the total lifetime cost for a patient with spina bifida was US$620,484 including the cost of medical care, indirect costs and development services. Also, children with spina bifida require adults spend time for medical appointments, helping children in mobility and toileting activities and taking children for treatment. The spina bifida patients require intensive and on-going medical attention. Thus, one can conclude that caregivers can either balance their careers or balance their working schedule, with the consequence of productivity losses. [33]

SGD 10-Reduced inequalities- Most of the burden of nutrient deficiencies is faced by low and the middle-income countries, which resulted in greater risk of death, morbidity and vulnerability to negative health outcomes that could be alleviated. To fight development challenges, the fortification was ranked as the third largest opportunity. [33]

The problems of vitamin and mineral deficiencies were faced by low- middle- as well as high-income countries and SDG was aimed to overcome inequalities between and within nations. The salt fortification with iodine, milk fortification with vitamin D and wheat and maize flour fortification with thiamine and niacin in the 1920s, 1930s and 1940s eradicated diseases like goitre, rickets, beriberi and pellagra in the United States. [33]

SDG 11- Sustainable cities- The residents of urban areas are more likely to get benefited of flour and rice fortification. To improve public health mass food fortification is an effective way but is sometimes overlooked as it doesn't reach poor. The larger number of people lives in cities than rural areas and around 30% urban dwellers reside in slum conditions. China, India, Brazil, Pakistan and Bangladesh included 431 million people in urban slum population. The fortification of grain provides an opportunity to enhance intake of nutrients in a significant proportion of population counting urban poor also. [33]

For effective fortification programmes and to address the challenges of nutritional deficiencies in vulnerable population and among others, the key players are:

- dominant individual to support fortification

- an institution with research capacity to monitor the impact
- food industry to fortify food
- policymakers to ensure nationwide fortification
- regulatory agencies for ensuring and monitoring compliance

The primary consideration for fortification is a national alliance in-country followed by participation by public, private and civic sectors and thereby, creating an understanding of health and economic benefits of food fortification. [33]

IMPACT OF OTHER TECHNOLOGIES ON METHODS OF FOOD FORTIFICATION

To attain necessary level of nutrients in fortifying foods, the processing and storage losses must be estimated by the manufacturers. The storage and processing losses and fortification procedures were affected by the introduction of new processes, equipment and packaging materials. [18]

Thermal processes- aimed at the destruction of micro-organisms, inactivation of enzymes and toxic factors and flavour and texture modification. The selection of heat treatment is done on the basis lethality of the process to provide safe product understated storage conditions. [34]

Packaging Materials- In thermal processing, use of retort pouches and deformable containers affects processing procedures followed by thermal degradation of nutrients. The packaging plays an essential role in the application of aseptic processing technologies and has implications for fortification techniques. For aseptically processed foods shelf life can surpass 1 year and required overages can be calculated by considering the storage loss over the entire period. The product is cooled preceding packaging in sterile containers during aseptic processes, resulting in higher levels for headspace oxygen and dissolved oxygen than in hot-filled products or traditional thermal process requiring vacuum sealing before processing. The loss of vitamin problems in aseptically processed foods has been ascribed to dissolve and headspace oxygen, oxygen and light permeability of the packaging material and storage temperature dependent, commodity-specific reaction. Due to dissolved and headspace oxygen, quick initial losses of vitamin C activity have been observed in aseptically processed milk followed by folate losses as vitamin C plays a major role in folate protection. Heavy losses of vitamin B_6 and B_{12}losses have also been reported during storage of aseptically processed milk (Oamen, 1989). [18]

Irradiation and Microwaves- Food processing uses irradiation to a limited extent and does not impact upon fortification procedures to a large extent. It is commonly used in the prevention of insect infestation in grains. Upon irradiation, there is a higher loss of Vitamin B_1in milled grains as compared to whole grains. The exclusion of oxygen reduces the vitamin loss during storage and irradiation. [35]

The effectiveness of fortification technology is boosted by efforts of research and development. Stability of iodine compounds in salt and vitamin A in cooking oils is improved by better refining procedures and packaging. The absorption of foods fortified with iron is enhanced by the use of stabilizers and enhancers. [11]

REGULATIONS AND STANDARDS

For effective food fortification, the government should ensure laws and regulations providing legal authority and proper regulatory framework. The regulatory controls and fortification standards safeguard consumers from the risk of purchasing and consuming nutritionally inadequate, misbranded or unsafe food. [11] All fortified foods must be manufactured, packed, labeled, handled, distributed and sold only in compliance with the specified standards under provisions of the Act and regulations. [17]

MONITORING AND EVALUATION

There is a great need to monitor the quality of fortified product and its micronutrient content due to increasing food fortification programs all over the world. The contribution of micronutrient in the alleviation of micronutrient deficiencies also needs to be evaluated. The fortified product must encompass adequate micronutrient and must be ensured that it reaches the targeted population. The production level monitoring is important and is done via quality assurance, the monitoring at different levels of distribution chain-from production to warehouse following sale, retail and household level also need to be done. [11]

The biological impact evaluation, to demonstrate effectiveness must be conducted after 2 or 3 years to determine how well the micronutrients are absorbed and contributed in reducing the occurrence of deficiency in the population. The nutritional status of women of childbearing age showed intense improvement in reducing neural tube defects by folic acid fortification. [11]

GLOBAL FOOD FORTIFICATION EXPERIENCE

Over the last 70 years in developed and developing countries, the major role was played by food fortification on the health of the population by eliminating many nutritional deficiencies. The effectiveness of food fortification in eliminating micronutrient deficiencies has been demonstrated in various studies. The flour fortification in Canada was done with vitamin B in 1944 and dropped the deficiency to negligible levels within 4 years. The 30-70% neural tube defects in newborns were reduced in the United States, Canada and Chile upon introduction of mandatory folic acid fortification of cereal-grain after 1998. The fortified breakfast cereals in France, Ireland, Spain and the United Kingdom demonstrated increased intakes of vitamins and minerals in comparative dietary survey analysis. The national fortification programs were introduced in Denmark by 1987 and in Spain by 1994. [11]

The rapid growth of fortified foods was seen in the last two decades. The fortification of salt with iodine is most successful fortification and iodized salt is used by the major population in 130 countries. About 70 million newborns each year are protected from the risk of mental impairment resulted by iodine deficiency since 2006 and two-thirds of salt consumed by developing countries is iodized salt (UNICEF, 2006). The double fortification of salt with iodine and iron has gained attention and is produced in India and further distributed in many countries to weaker segments of the population through public programs and commercial channels. [11] The double fortified salt showed improvements in iron deficiency indicators such as haemoglobin, ferritin and body iron in a randomized controlled double-blinded study after 9 months in women tea pickers. [36] The single-blinded controlled efficacy study done in tribal areas of East Godavari district, AP and double-blinded controlled study in schools of Hyderabad by NIN showed a notable reduction in anaemia. [37] Over 80 countries mandated cereal grain fortification and many countries are fortifying milk and edible oils. [17]

The staple foods fortification with micronutrients has grown significantly. The 28% of global market in more than 63 countries is fortifying flour with iron, folic acid and other nutrients. The fortification of wheat and industrially milled corn flour has grown widely in the United States and wheat flour fortification has grown with excessive interest in South and South-East Asia. In the Middle East and North Africa, iron and folic acid have been added to cereal flour in several countries. [11] The impact of fortified wheat flour was tested in a study on anaemia prevalence in Darjeeling, showed decrease levels of anaemia in adolescent girls, pregnant and lactating women and school-age children. [38]

At present, 14 countries mandated milk fortification of which 11 fortifies milk

with both vitamin A and D. Costa Rica is fortifying milk with iron and folic acid while Canada and China are adding calcium, Vitamin A and D to milk. The milk fortification resulted in 18% lesser incidents of diarrhoea and 26% lesser incidents of pneumonia. [17]

The FSSAI of India at National Summit on Food Fortification in 2016 launched standards for fortification of staple foods like wheat flour, rice, oil, milk and double fortified salt. The fortified logo was launched by FSSAI to promote and differentiate regular products and fortified products (Figure 3). The square around +F represents completeness while plus sign represents an addition of extra nutrition by vitamins and minerals to daily nutrition requirements. The ring represents good health, protection for healthy and active life. This creates awareness among customers and helps in selecting healthier food choices. [17]

Figure 3-Fortification logo

In Asia, national flour fortification has been implemented in Nepal, Pakistan and some states of India. The wheat and maize flour fortification became mandatory in Nigeria and South Africa. The iron fortification of condiments like fish/soy sauces emerged in Asia including China, Thailand and Vietnam. In Central America, the deficiency of vitamin A is eliminated by Guatemala's sugar fortification program. [11] In India, the government runs several programmes involving fortification, aims at enhancing nutrient levels. The Mid-Day Meal (MDM) Scheme provides fortified grains for children studying in schools up to 8th class as part of hot cooked meal served at school daily. Around 2.16 million MT of food grains are allotted by government every year to feed 118.5 million children. The Integrated Child Development Scheme (ICDS) supplies supplementary nutrition in Take Home Ration (THR) for pregnant women, lactating mothers and children and hot cooked meal for children of age group 3-6 years. [17]

The cooking oils in Nigeria, Morocco, Yemen, Bangladesh, and Pakistan are fortified with vitamin A. The anaemia is reduced from 21% to 1% in Chilean infants upon implementing national program providing fortified milk to infants. [11]

The lozenges are fortified and distributed to pregnant and lactating mothers, adolescent girls and children of 2-5 years of age in India, providing assurance of measured quantity intake and high compliance for micronutrients. [11]

RISKS AND PROBLEMS ASSOCIATED WITH FOOD FORTIFICATION

The food fortification often leads to excess intake of nutrients in individuals. The fortified processed products are safe, although the risk may be associated with some of them ranging from mild to severe.

- **Nutrient overdose**-The excess addition of vitamins and minerals pose serious risks. The excess vitamin A intake reduces bone density also increases birth defect risks and liver damage. The risk of haemorrhagic stroke increases with excessive intake of vitamin E. As per review was done by Annals of Internal Medicine intake of excessive amounts of β-carotene then recommended could lead to higher mortality risk. [39] The excessive iron intake may cause cirrhosis, cardiovascular disease, type 2 diabetes and cancer. The populations with genetic and acquired diseases are at greater risk in case of mass fortification and needs to be protected. [40]
- **Health risk**- Although there is no direct association of fortified foods with overweight and obesity are higher in

calories with respect to whole foods and create a desire to eat more resulting in weight gain over the time. [39]

- **Medication complications**- Fortified foods may result in harmful interactions with people taking other prescription medications. The fortification of foods with vitamins and minerals may result in events of decreased absorption, failure of treatment and increased mortality risk. [39]

To establish dietary patterns and habits, surveys are to be done in many countries to provide critical inputs in determining appropriate vehicles to be used in food fortification. [18]

CONCLUSION

Processing of food involves the loss of nutrients, in order to counter such losses foods are enriched with nutrients. This review focuses on the implications of fortification of foods with vitamins and minerals essential for the health of individuals and commonly used food vehicles in detail. The review also includes the micronutrient deficiencies in the vulnerable population mainly women and children and also the impact of fortification in enhancing the quality of health. Food fortification is a nutritional intervention program with a specifically defined target population and its effectiveness depends on whether or not, the fortified food is accepted, purchased and consumed by the targeted population. Staple foods are fortified by the government or other authoritative bodies with the objective of overcoming endemic nutritional diseases such as salt fortification with iodine or milk fortification with Vitamin A which resulted in the prevention of goitre and vitamin A deficiencies in various countries including India.

REFERENCES

1. WHO. World Health Report 2000. Health Systems: Improving Performance. Geneva: World Health Organization; 2000. 206p.
2. Black RE. Micronutrients in pregnancy. Br J Nutr. 2001;85(S2):S193-S197.
3. Black RE, Allen LH, Bhutta ZA, Caulfield LE, De Onis M, Ezzati M, Mathers C, Rivera J. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet. 2008;371(9608):243-260.
4. WHO. Global prevalence of vitamin A deficiency in populations at risk 1995-2005. WHO global database on vitamin A deficiency. Geneva: World Health Organization; 2009. 55p.
5. *Allen LD, de Benoist B, Dary O and Hurrell RE. Guidelines on Food Fortification with Micronutrients. Geneva, Switzerland: WHO and FAO;2006.* 341p.
6. Leslie J. Women's nutrition: the key to improving family health in developing countries. Health Policy and Plan. 1991;6(1):1-19.
7. Caulfield LE, Zavaleta N, Shankar AH, Merialdi M. Potential contribution of maternal zinc supplementation during pregnancy to maternal and child survival. Am Journal Clin Nutr. 1998;68(2):499S-508S.
8. Benoist B, McLean E, Egli I, Cogswell M. Worldwide prevalence of anaemia 1993–2005: WHO global database on anaemia. Geneva: World Health Organization; 2008. 40p.
9. McLean E, de Benoist B, Allen LH. Review of the magnitude of folate and vitamin B12 deficiencies worldwide. Food Nutr Bull. 2008;29(2):S38-51.
10. Das JK, Salam RA, Kumar R, Bhutta ZA. Micronutrient fortification of food and its impact on woman and child health: a systematic review. Systematic reviews. 2013;2:67.
11. Venkatesh Mannar MG, Wesley Annie. Food Fortification. International Encyclopedia of Public Health. 2008; 622-630
12. Burgi H, Supersaxo Z, Selz B. Iodine deficiency diseases in Switzerland one hundred years after Theodor Kocher's survey: a historical review with some new goitre prevalence data. Acta Endocrinologica. 1990;123(6):577-590.
13. Marine D, Kimball OP. Prevention of simple goiter in man. Archives of Internal Medicine. 1920; 25(6):661-672.
14. Centers for Disease Control. Recommendations for the use of folic acid to reduce the number of cases of spina

bifida and other neural tube defects. MMWR Recomm Rep. 1992;41(RR-14):1-7.
15. Institute of Medicine authors. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. Washington (DC): National Academy Press (US); 1998.
16. U.S. Preventive Services Task Force authors. Folic acid for the prevention of neural tube defects: U.S. Preventive Services Task Force recommendation statement. Ann Intern Med. 2009;150 (9):626–631.
17. FSSAI. Large Scale Food Fortification in India- The Journey So Far and Road Ahead. 2017[updated 2017 Oct. 17; cited 2018 March 10]. Available from www.fssai.gov.in/dam/jcr:c746d723-ebb1.../Large_scale_Food_Fortification.pdf
18. Food and Agricultural Organisation (UN). Food Fortification: Technology and Quality Control. 1995.[updated 1995 November 20-23; cited 2018 March 10] Available fromhttp://www.fao.org/docrep/W2840E/w2840e0b.htm
19. Mother, Infant and Young Child Nutrition and Malnutrition [Internet]. 2018 [updated 2018Dec. 23; cited 2018 March 10] Available from http://motherchildnutrition.org/malnutrition/about-malnutrition/common-micronutrient-deficiency-diseases.html
20. Food Fortification Initiative. Why fortify food and rice? [Internet]. [cited 2018 March12] Available fromhttp://ffinetwork.org/why_fortify/index.html
21. What are fortified foods? Definition & Examples[Internet]. [cited 2018 March 12] Available from https://study.com/academy/lesson/what-are-fortified-foods-definition-examples.html
22. Fortified food: should we really be pumping bread with Vitamin D[Internet]. 2015 [updated 2015 June 08; cited 2018 March 12] Available from https://www.telegraph.co.uk/foodanddrink/healthyeating/11659059/Fortified-food-should-we-really-be-pumping-bread-with-Vitamin-D.html
23. Anargyros N Moulas. Fortification of foods with vitamin D.Journal of Biotechnology. 2017; 256:S13.
24. Sahu SK, Kumar SG, Bhat BV et al. Malnutrition among under-five children in India and strategies for control. J Nat SciBiol Med. 2015;6(1):18-23.
25. Grebmer KV, Saltzman A, Birol E et al. Global hunger index: The Challenge of Hidden hunger. Washington: International Food Policy Research Institute;2014.56p.
26. World Health Organization. The Global prevalence of anemia in 2011. Geneva: World Health Organization. 2015. 43p.
27. Dobe M, Garg P, Bhalla G. Fortification as an effective strategy to bridge iron gaps during complementary feeding. Clinical Epidemiology and Global Health. 2017; 10.1016/j.cegh.2017.11.001.
28. Black R. Micronutrient deficiency--an underlying cause of morbidity and mortality. Bulletin of the World Health Organization. 2003;81(2):79.
29. Boosting India's nutrition- the key lies in food fortification[Internet]. 2017 [updated 2017 Sept. 28; cited 2018 March 10] Available form http://scroll.in/bulletins/84/boosting-indias-nutrition-the-key-lies-in-food-fortification.
30. Report of joint FAO/WHO expert consultation. Human vitamin and mineral requirements. Rome: FAO; 2002. 286p. Available from http://www.fao.org/docrep/004/y2809e/y2809e0d.htm#bm13
31. Bhan MK, Sommerfelt H, Strand T. Micronutrient deficiency in children. British Journal of Nutrition. 2001;85(2):199-203.
32. Office of Dietary Supplements. National Institutes of Health. Vitamin D Fact sheet for Health Professionals. Available from :http://dietary-supplements.info.nih.gov/factsheets/vitamind.asp (cited 2018 March 12)
33. Food Fortification Initiative. Fortify to Address Sustainable Development Goals. Available from http://www.ffinetwork.org/why_fortify/SDGs.html (cited 2018 March 12)
34. Ryley J, Kajda P. Vitamins in thermal processing. Food Chemistry. 1994;49(2):119-129.
35. Kilcast D. Effect of irradiation on vitamins. Food Chemistry. 1994;49(2):157-164.
36. Haas JD, Rahn M, Venkatramanan Set al. Double-fortified salt is efficacious in improving indicators of iron deficiency in

female Indian tea pickers. The Journal of Nutrition. 2014;144(6):957-964.
37. National Institute of Nutrition. Double Fortified Common Salt (DFS) as a tool to control Iodine Deficiency Disorders and Iron Deficiency Anaemia. National Institute of Nutrition; 2005. 12p.
38. Vir SC. Public Health and Nutrition in Developing Countries (Part I and II). New York: WPI Publishing; 2011. 1244p.
39. Schuna C. What Are the Dangers of Fortified Foods and Supplements? [Internet]. Healthy Eating SF Gate. Available from http://healthyeating.sfgate.com/dangers-fortified-foods-supplements-11621.html(Cited 2018 April 19).
40. Blanco-Rojo R, Vaquero MP. Iron bioavailability from food fortification to precision nutrition. A review. Innovative Food Science & Emerging Technologies. 2018; 10.1016/j.ifset.2018.04.015.

How to cite this article: Nagar L, Popli H, Gupta A et al. Food fortification to combat micronutrient deficiencies and its impact on sustainable development goals. Int J Health Sci Res. 2018; 8(7):307-320.

******