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Fortification of Food with Micronutrients for Meeting Dietary Requirements: A Review

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Review Article

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Abstract

Hidden hanger is a manifestation of malnutrition which diminishes the health of the people all over the world, its effect is worse when it comes to the developing countries. More than two hundred million people worldwide are suffering from micronutrient deficiency. The risks of micronutrient deficiency are high in vulnerable groups of people such as infants, children, adolescents, and pregnant women. Maternal mortality, growth retardation, cognitive impairment, impaired work capacity, goiter and blindness are among the many risks which occur in the population as a result of micronutrients deficiencies in the human body. Among micronutrients vitamin A, iodine and iron are the most nutritionally important nutrients in terms of public health problems and known to affect one third of the world population specifically in developing countries. To alleviate the problem of micronutrient deficiency, adequate consumption of micronutrients in the daily diet is a perquisite. However, meeting the dietary requirements of the human body to mitigate the accompanying micronutrient deficiency in a regular diet is not possible mainly in poor populations due economic deprivation and other many factors. Thus, several strategies including supplementation of food, dietary diversification, nutrition education, public health and food safety measurement and food fortification have been designed to reduce the problem of micronutrient deficiency and improve the nutritional status of the population. Among the strategies, food fortification is found to be very effective to eliminate micronutrient deficiency from the population without noticeably changing the people's eating style and culture. Accordingly very essential micronutrients such as iodine, iron, zinc, and vitamin A are fortified with different food products mainly staple foods to address the micronutrient deficiency problems in the most vulnerable people groups around the world. Thus, this review concluded that micronutrient fortification of food is indispensable option to meet the dietary requirements and reduce associated health risks of micronutrient deficiencies in most vulnerable groups of the population around the globe without causing significant effect on the people's economy and eating culture.

Keywords: Fortification; Vitamin A; Iodine; Zinc; Iron

Introduction

Background

Micronutrient deficiencies are one of the factors that affect the health of the human world widely. It accounts for a majorly hidden but often devastating form of malnutrition. Around two billion people are affected due to micronutrient deficiencies in the world and which causes many health risks including goiter, blindness, anemia, cognitive impairments, impaired work capacity and maternal mortality [1]. Several intervention mechanisms have long been practiced to combat micronutrient deficiencies which were among the most cost-effective public health programs. It is recommended that adequate micronutrients in the daily diet are one of the perquisites for reduction of micronutrient deficiency. Thus, to halt the problem of micronutrient deficiency, fortification of staple foods with certain micronutrients are proven to very efficient such as the iodization of salt, fortification of wheat flour with iron, and fortification of vegetable oil with vitamin A [2].

Food fortification is the deliberate addition of one or more micronutrients to the food products to provide a health benefit effect and mitigate a demonstrated deficiency in the population [3]. Accordingly, "food fortification has been defined as the addition of one or more essential nutrients to a food, whether or not it is normally constituted in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups". Therefore, food fortification is regarded as being the most inexpensive and effective way to eliminate dietary micronutrient deficiencies from the population. In addition, it is socially acceptable, does not change the characteristics of the food, requires no changes in food habits, has readily visible benefits and can legally be enforced for a nationwide action [4].

Deficiency of iron, iodine and vitamin A are three most important worldwide health problems and presumed to affect at least one third of the world's populations mainly people living in the developing countries. It is reported that over 2 billion people are anaemic, nearly 2 billion have inadequate iodine nutrition and over 254 million preschool-aged children are deficient in vitamin A [3]. Nowadays, zinc deficiency is also becoming more prevalent to the people especially to children and infants. Thus, adequate zinc nutrition is essential for human health because of zinc's critical structural and functional roles in multiple enzyme systems that are involved in gene expression, cell division and growth and immunologic and reproductive functions. As a consequence, zinc deficiency affects children's physical growth and the risk and severity of a variety of infections [5].

Different types of approach has been followed to improve micronutrient status of the people, including supplementation of food, dietary diversification, nutrition education, public health and food safety measurement and finally food fortification [6]. Among those intervention mechanisms food fortification is considered a cost-effective strategy to improve micronutrient status and numerous studies have documented the efficacy and effectiveness of fortification programs. However, its effectiveness depends on selection of suitable food vehicles and adequate levels of micronutrients in the fortified food, which need reliable baseline food and nutrient intakes assessments, appropriate regulations and quality control measures, and continuous monitoring and evaluation program. Moreover, the fortified foods must be consumed by the intended populations which are at risk of micronutrient deficiency [7]. Therefore, this paper has reviewed the micronutrient fortification foods for meeting dietary requirements to eliminate associated health risk problems and improve the nutritional status of the people around the world.

Fortification of Food with Selected Micronutrients

Among micronutrient deficiency intervention strategies, fortification of food with micronutrients is the best strategy around the globe specifically in the developing world. It is a strategy that best suits technologically, programmatically and economically to effectively address the micronutrient intakes of the populations. Fortification was aimed to deliver certain micronutrients to target specific health conditions such as goitre with iodized salt; rickets with vitamin D-fortified milk; beriberi, pellagra and anaemia with B-vitamins and Fe-enriched cereals in early 20th century [8].

Vitamin A

Vitamin A is one of the essential micronutrients which are required in small amounts for the normal functioning of the visual system, the maintenance of cell function for growth, epithelial cellular integrity, immune function and reproduction in the human body. The dietary requirements of vitamin A are provided as a mixture of preformed vitamin A (retinol) and provitamin A (arotenoids), which are present and derived from animal source and vegetable origin foods respectively [3]. Even though vitamin A, required in small amounts for the health of humans, most people are suffering with vitamin A deficiency. Especially in developing world vitamin A deficiency mostly affects preschool-aged children and lactating women and sometimes school-aged children and adolescents are also affected [9].

To combat vitamin A deficiency particularly in developing countries, food fortification has played a great role. The goal of a vitamin A fortification is to prevent vitamin A deficiency by increasing vitamin A intake and improving vitamin A status among population groups whose daily dietary needs for vitamin A are not routinely met, while minimizing the risk of overconsumption among groups whose vitamin A status is normal [10].

Prevalence of Deficiency: Vitamin A deficiency results in serious health effects on the people living around the globe. Especially vitamin A deficiency affects the groups who are living in low-income countries, thus the prevalence of vitamin

A is higher in preschool-aged children, school-aged children through adolescence and women of reproductive age, especially during pregnancy and lactation [10]. The vitamin A status of the affected group can be identified traditionally using visual observation of their eyes, especially blindness and xerophthalmia, since vitamin A deficiency affects visual function, which indicates clearly the changes of the eyes (Table 1).

Region	Children < 5 yr				Pregnant women			
	Serum retinol		Xerophthalmia		Serum retinol		Night-blindness	
	< 0. 70 µmol/L			< 1. 05 µmol/L				
	%	No. (millions)	%	No. (millions)	%	No. (millions)	%	No. (millions)
Africa	44. 5	56. 4	2. 0	2. 55	13. 5	4. 2	9. 8	3. 02
The Americas	15. 6	8. 7	0. 6	0. 36	2. 0	0. 2	4. 4	0. 50
South/south east Asia	49. 9	91. 5	0. 5	1. 01	17. 3	6. 7	9. 9	3. 84
European region	19. 7	5. 8	0. 8	0. 24	11. 6	0. 7	3. 5	0. 22
Eastern Mediterranean	20. 4	13. 2	1. 2	0. 77	16. 1	2. 4	7. 2	1. 09
Western Pacific	12. 9	14. 3	0. 2	0. 26	21. 5	4. 9	4. 8	1. 09
Total	33. 3	190	0. 9	5. 17	15. 3	19. 1	7. 8	9. 75

Table 1: Prevalence and numbers of cases of preschool-aged child and antenatal vitamin A deficiency and xerophthalmia by region.
Source: Klemm, et al. [10].

About 3 million preschool-aged children exposed ocular signs of vitamin A deficiency worldwide, which more commonly assessed using serum or plasma retinol levels. Moreover, according to WHO report 254 million preschool-aged children have low serum retinol levels throughout the world which can be regarded as clinically or subclinically vitamin A deficient. In the developing world, prevalence rates in this age group range from 15% up to as high as 60%, with Latin America, the Eastern Mediterranean and the Western Pacific being at the low end of this range, and Africa and South-East Asia occupying the high end [3].

Risk Factors for Deficiency: Vitamin A deficiency can be developed in humans due to different factors. It is most common in populations consuming most of their vitamin A needs from provitamin carotenoid sources and where minimal dietary fat is available. It is reported that around 90% of the ingested preformed vitamin A is absorbed but the absorption efficiency of provitamin A carotenoids varies widely, depending on the type of plant source and the fat content of the accompanying meal. Where possible, an increased intake of dietary fat is likely to improve the absorption of vitamin A in the body [11].

Vitamin A deficiency usually happens in an environment of ecological, social and economic deprivation, in which the key risk factors for vitamin A deficiency are low vitamin A diet source (i. e. dairy products, eggs, fruits and vegetables), poor nutritional status, and a high rate of infections, in particular, measles and diarrhoeal diseases. Animal sources of foods are the best sources for vitamin A, in particular, liver, eggs and dairy products, which contain vitamin A in the form of retinol, i. e in a form that can be readily used by the body. It is not surprising then that the risk of vitamin A deficiency is strongly inversely related to intakes of vitamin A from animal source foods. In fact, it is difficult for children to meet their requirements for vitamin A if their diet is low in animal source foods, especially if their diet is also low in fat. Fruits and vegetables contain vitamin A in the form of carotenoids, the most important of which is β-carotene. In a mixed diet, the conversion rate of β-carotene to retinol is approximately 12:1 [3].

Choice of Vitamin A Fortificant: The characteristics of the food vehicle, as well as various technological, regulatory and religious considerations largely govern the choice of a vitamin A fortificant. Retinol (preformed vitamin A) is an unstable compound; it is esterified in commercial preparations, usually with palmitic or acetic acid, to the more stable corresponding esters. Retinyl acetate and retinyl palmitate, along with provitamin A (β-carotene), are thus the main commercial forms of vitamin A that are available for use as food fortificants. The intense orange colour of β- carotene makes it unsuitable for use as a fortificant in many foods, but it is widely used to give an orange-yellow colour to margarines and beverages. Vitamin A is easily added to fat-based or oily foods due to its fat solubility. An encapsulated form of the vitamin is needed when the food vehicle is either dry or a water-based liquid. Based on this distinction, vitamin A fortificants can be divided into two categories:

- ✓ Oily forms that can be incorporated directly into fat-based foods or emulsified into water-based ones (e. g. milk).
- ✓ Dry forms that can be dry mixed into foods or dispersed in water, depending on whether they are cold water dispersible or non-cold water dispersible.

Pure vitamin A and β-carotene in solution are unstable when exposed to ultraviolet light, oxygen or air. Thus all forms of vitamin A – oily or dried – are protected with antioxidants to prolong their shelf-life [3].

Vitamin A Fortified Foods: Different foods can be fortified with vitamin A; especially, oil, margarine, and sugar are suitable for vitamin A fortification. Fortification with vitamin A has also been tried with whole-wheat grain, tea, instant noodles, fish sauce, yogurt and salt. Fortification of foods with vitamin A is a potentially effective intervention to prevent or control vitamin A deficiency in low-income countries where undernutrition and poverty coexist [10].

Oils: Oil is an ideal food for vitamin A fortification; this is due to its fat solubility, well established procedure and can be implemented with low cost. In addition, oil can stabilize retinol and delay oxidation of vitamin A. Not only does oil protect vitamin A from oxidation but also facilitates absorption of the vitamin. Although the technology for adding vitamin A to oils is simple and inexpensive, and oils are widely used, the fortification of oils with this vitamin is relatively rare, at least compared with that of margarines. The fortification of oils is thus a potentially useful means of expanding the present range of vitamin A fortified foods [9].

During vitamin A fortification of oil, stability may be a problem in some settings; experimental studies have shown that when vitamin A is added to soybean oil in sealed cans, the vitamin was stable for up to 9 months. Another study indicated that less than 15% of the vitamin A has been lost during boiling or pressure cooking of rice or beans while about 60% has been lost when the oil was reused several times for frying [3].

Margarine: Similar to oil, margarine and other hydrogenated oil products are the most suitable vehicles for vitamin A. In many countries vitamin A is added to margarines to imitate the nutritional value of butter, which margarine has often replaced. Vitamin A fortification of margarine was initiated in Denmark in the 1920s, when cases of nutritional blindness appeared after butter was replaced with nonfortified margarine. Several countries fortify margarine at levels ranging from 1to 15 mg/kg as either a mandatory or a voluntary practice [9]. Like that of oil margarine also protects the vitamin A from oxidation during storage and also facilitates absorption of the vitamin. Vitamin A fortification of margarine in Newfoundland, Canada, for example, resulted in a marked improvement in vitamin A status [3].

Cereal Flours: Fortification of cereal flours is largely practiced throughout the world because of its availability and accessibility for human consumption. At the same time fortification of cereal flours with vitamin A is technically feasible, and nutrient stability in the products is good because cereal flour production usually incorporates enzymes, oxidants and other substances. For instance, Venezuela has had a national program fortifying precooked corn flour since 1993. The flour is fortified with vitamin A at 2.7 mg/kg, which contributes approximately 30% of the vitamin A RDI assuming a consumption of 80 g/d and 15% losses of the vitamin A during handling and storage of the flour, as well as food preparation [9].

Fortification of cereal flours with vitamin A is a basic strategy because wholegrain cereals and flours contain negligible amounts of intrinsic vitamin A and largely consumed by vulnerable groups, so that it could address the daily requirements of vitamin A. Therefore, flours are, nevertheless, potentially good vehicles for vitamin A fortification, because dry forms of vitamin A can easily be mixed in with other additives. Despite this, cereal flours are not fortified with vitamin A in most industrialized countries, because, for historical reasons, margarines are the preferred vehicle and, furthermore, because vitamin A deficiency is no longer a significant problem. It is reported that wheat flour is fortified with 4.5 mg retinol/kg in some mills in the Philippines, a practice which provides an average concentration in bread of 2.2μg retinol/g. This accounts for 33% of the recommended daily intake of vitamin A for school-age children. At this level of fortification, retinol liver stores in deficient children were significantly increased at the end of a 30-week efficacy trial [3].

Sugar: Sugar is consumed largely in the world including in low-income countries and fortification of sugar with vitamin A is highly recommended in developing countries due to the highly prevalence of vitamin A deficiency. Among the many approaches that have been taken so far to control vitamin A deficiency, sugar fortification seems to be the most cost-effective method. According to a UNICEF report, the cost of sugar fortification is about one-fifth of that of other interventions in Guatemala. This is due to the success of the sugar-fortification programme in Guatemala that was conducted in the mid of 1970 two years and initiated again and maintained since 1988, this approach has become the preferred intervention in those countries where it is feasible [12]. Sugar is a good vehicle for fortification in countries where it is centrally produced in a few plants and is widely consumed by most of the population because now a day's salt was consumed in very small amounts and its quality was inadequate; oil/margarine and wheat flour were neither widely distributed nor consumed by the neediest individuals; dairy products were scarce [9].

Iodine: Iodine is present in the body in minute amounts, mainly in the thyroid gland and which play in the synthesis of thyroid hormones. Iodine deficiency is a major public health problem for populations throughout the world, but particularly for young children and pregnant women, and it has also a significant threat to national social and economic development. The most devastating outcome of iodine deficiency is mental retardation: it is currently one of the world's main causes of preventable cognitive impairment [3]. Iodine deficiency is the world's single most significant cause of preventable brain damage and mental retardation affecting 118 countries worldwide. Iodine deficiency disorders (IDD) which collectively coined for the clinical and subclinical manifestations of iodine deficiency, affect all stages of human life and encompass a variety of conditions including goitre, cretinism, dwarfism, mental retardation, muscular disorders, spontaneous abortions and stillbirths [13].

Prevalence of Iodine Deficiency: Around 70% of the world's population is estimated to use iodized salt in a total of 130 countries to protect the adverse effect of iodine deficiency and it has been estimated that close to 79 million infants are born with some degree of protection from the adverse consequences of iodine deficiency [14]. The recommended indicators for assessing the extent of iodine deficiency within a population are median urinary iodine and total goitre prevalence. According to generally accepted criteria, iodine deficiency is a public health problem in populations where the median urinary iodine concentration is below 100µg/l, or in areas where goitre is endemic (where more than 5% of children aged 6–12 years have goiter). As the median urinary iodine concentration reflects current iodine intake and responds relatively rapidly to the correction of iodine deficiency, it is usually the preferred indicator for monitoring the impact of interventions for IDD control [3]. The health problems that result when dietary iodine intake is below physiologically required level are known as iodine deficiency disorder. Globally, IDD is one of the well-known nutritional deficiency disorders [15].

Risk Factor for Deficiency: The human body contains about 15-20 mg of iodine of which about 70-80% is in the thyroid gland. Thus, dietary iodine is absorbed throughout our gastrointestinal tract. The known physiological functions of iodine are exclusively linked to thyroid hormones. In adequate iodine intake is closely related to lowered thyroid function, which results in IDDS. If dietary iodine intake is below physiological required levels the thyroid hormone cannot be synthesized to sufficient level. Thyroid hormone involved in the regulation of various enzymes and metabolic processes, and iodine deficiency impairs several physiological functions [15]. Therefore, the main factor responsible for the development of iodine deficiency is a low dietary supply of iodine. This tends to occur in populations living in areas where the soil has been deprived of iodine as the result of past glaciation, and subsequently, because of the leaching effects of snow, water and heavy rainfall. Iodine deficiency is exacerbated by a high consumption of natural goitrogens that are present in some staple foods such as cassava. The antithyroid action of goitrogens is associated with the presence of thiocyanate which cause inhibition of thyroid iodide transportation and, at higher doses, competes with iodide in the synthesis of thyroid hormones. The balance between the dietary supply of iodine and thiocyanate used to determined goitogenecity. Thus, goitre develops when the urinary iodine (µg) and thiocyanate (mg) ratio falls below 3 [3].

Choice of Iodine Fortificant: In fortification of food with iodine, two chemical forms of iodine are most suitable for food fortification, namely, iodide and iodate. The fortificants commonly used are potassium iodide (KI) and potassium iodate (kIO_3). Potassium iodide has been used as an additive in bread and salt for about 80 years, and potassium iodate for about 50 years [16]. Iodates are less soluble in water than the iodides, more resistant to oxidation and evaporation, and being more stable under adverse climatic conditions, does not require the co-addition of stabilizers. Although more expensive, potassium iodate is thus preferred to potassium iodide, especially in hot and humid climates, and is recommended as an additive for many foods, including salt. For historical reasons, however, countries in Europe and North America still use potassium iodide, while most countries with tropical climates use potassium iodate [3].

Iodine Fortified Foods

Salt: Salt is the most widely used food vehicle for iodine fortificants. In many countries, iodisation food salt is common as the main or sole measure to address iodine deficiency. Iodised salt has been found to be a suitable substitute for non-iodised salt in the majority of foods tested with minimal impact on taste and appearance. In contrast, there is a paucity of evidence as to the impact of the addition of iodine to food other than via salt [17]. WHO has also recommended universal salt iodization (USI), that is, the iodization of all salt for human (food industry and household) and livestock consumption as strategy for the control of iodine deficiency disorders. The choice of this strategy is because of salt is one of the few commodities consumed by everyone, fairly stable throughout the year, its production generally limited to a few geographical areas, salt iodization technology is easy to implement and available at reasonable cost throughout the developing world, the addition of iodine to salt does not affect its colour, taste or odour and the quality of iodized salt can be monitored at the production, retail and household levels [3].

Bread: Bread is a nutritious food that is typically made domestically for the local market and can be consumed by all groups with minimum cost. Bread is not mostly produced for import and export purpose, therefore reduced relative to foods with a large import and/or export component. Bread has a short shelf life and so is less likely to be affected by nutrient loss than products with longer shelf lives. Many researches indicated that iodised salt can successfully be added to bread. In practice, the salt, and hence iodine content, of commonly consumed bread is not as variable as in breakfast cereals and biscuits [17]. From a technical point of view, bread is a good vehicle for iodine and has been shown to be an effective way of ensuring a constant supply of dietary iodine. It has been used in a few European countries where bread is a staple food, such as Russia and in Tasmania. The main carrier for iodine in the Netherlands is the salt added to bread, i. e. baker's salt, which has been enriched with iodine since 1942 [3].

Milk: Milk and milk products are largely used in industrialized and developing nations. Thus, iodine-enriched milk has been instrumental in the control of iodine deficiency in several countries. However, this has been largely a consequence of the use of iodophors by the dairy industry rather than the result of a deliberate addition of iodine to milk. During the 1960s and 1970s, the uncontrolled use of iodophor-containing sanitisers inadvertently raised iodine levels in milk. Consequently tighter controls of iodophor sanitisers were introduced in the early 1970s in the dairy industry which brought changes to dairy industry practices. As a result, the iodine content of milk has decreased. Iodophors are still used as effective sanitisers in some sections of the dairy industry but their use today is more controlled and measured. Despite this decline, dairy foods still remain an important source of dietary iodine [17]. Therefore, iodine-enriched milk has become a major adventitious source of iodine in many countries in northern Europe, as well as in the United Kingdom and the United States [3].

Iron

Iron deficiency is the most common and widespread nutritional disorder in the world, and is a public health problem in both industrialized and nonindustrialized countries. Most of the iron in the human body is present in the erythrocytes as haemoglobin, where its main function is to carry oxygen from the lungs to the tissues. It is also an important component of various enzyme systems, such as the cytochromes, which are involved in oxidative metabolism. It is stored in the liver as ferritin and as haemosiderin. Iron deficiency is the result of a long-term negative iron balance; in its more severe stages, which causes anaemia. Anaemia is defined as a low blood haemoglobin concentration [3].

Prevalence of Deficiency: Iron deficiency is probably the most common nutritional deficiency disorder in the world. According to a recent WHO estimate, around 600–700 million people worldwide have marked iron deficiency anaemia and the bulk of these people live in developing countries. Whereas in developed countries, the prevalence of iron deficiency anaemia is much lower and usually varies between 2% and 8% [11]. About 40% of the world's population (i. e. more than 2 billion individuals) is thought to suffer from anaemia, i. e. low blood haemoglobin. The mean prevalence among specific population groups are estimated to be:

- ✓ 50% pregnant women, infants and children aged 1–2 years
- ✓ 25% preschool-aged children
- ✓ 40% schoolchildren
- ✓ 35% non-pregnant women

These average figures obscure the fact that iron deficiency and iron-deficiency anaemia are even more prevalent in some parts of the world, especially in the Indian subcontinent and in sub-Saharan Africa, where, for example, up to 90% of women become anaemic during pregnancy [3].

Risk Factor for Deficiency: Nutritional iron deficiency referred to when the diet is unable to supply enough iron to cover the body's physiological requirements. This is the most common cause of iron deficiency around the world. In many tropical countries, infestations with hookworms lead to intestinal blood losses that in some individuals can be considerable [15]. Many factors can be considered as a result of iron deficiency. The main risk factors for iron deficiency include

- ✓ a low intake of haem iron
- ✓ an inadequate intake of vitamin C (ascorbic acid)
- ✓ poor absorption of iron from diets high in phytate
- ✓ periods of life when iron requirements are especially high
- ✓ heavy blood losses as a result of menstruation, or parasite infections such as hookworm

In addition to the above factors, acute or chronic infections, including malaria, can also lower haemoglobin concentrations. The presence of other micronutrient deficiencies, especially of vitamins A and B12, folate and riboflavin, also increases the risk of anaemia [3].

Choice of Iron Fortificants: For food fortification, iron is the most challenging micronutrient due to the most bioavailable iron compounds tend to interact most strongly with food constituents to produce undesirable organoleptic changes. The choice of a suitable iron compound as a food fortificant, the overall objective is to find the one that has the greatest absorbability, meaning the compound which has the highest relative bioavailability1 (RBV) compared with ferrous sulfate, yet at the same time does not cause unacceptable changes to the sensory properties (i. e. taste, colour, texture) of the food vehicle and cost of the compound should also be fair. Currently many varieties of iron compounds are used as food fortificants. These can be broadly divided into three categories. Thus are water soluble, poorly water soluble but soluble in dilute acid and water insoluble and poorly soluble in dilute acid [3].

Iron Fortified Foods: Iron fortification is already widely practised in many parts of the world. For example, more than 20 countries in Latin America have implemented mass iron fortification programmes, most of which involve the fortification of wheat or maize flours. The other frequently used food vehicles include cereal-based complementary foods, fish sauce, soy sauce and milk. Salt has also been fortified with iron in efficacy trials. Products derived from cereal flours (e. g. bread, cereal snacks and breakfast cereals) are also useful food vehicles, but the amount of iron provided via this route will depend on the quantity of food eaten and on the level of fortification [3].

Flour: Cereal flours (wheat and maize) are currently the most common vehicles for iron fortification to reach the general population. Flour, bread, and cereals are suitable vehicles for iron fortification in Western countries, as these are frequently consumed, staple foods. Bread is a particularly useful vehicle as the risk for organoleptic deterioration due to the pro-oxidative properties of iron is lower compared to other foods with a higher lipid content and longer shelf life [18].

Enrichment of wheat flour is being adopted by more and more countries as a means of combating micronutrient malnutrition. Thus, iron fortified wheat flour provides approximately 20% iron consumed in North America and nearly 40% in Sweden. In most developing countries, where the prevalence of IDA is several times higher than in developed countries, such a program is expected to have a positive impact on iron status, because, fortification of wheat flour is simple, cheap, and a major strategy for preventing anemia. A premix of the micronutrients to be added may be prepared or procured. The premix is then added to the flour at a uniform rate through a volumetric screw feeder located towards the end of the milling process. The premix can be fed directly on to the flour by gravity or by air convection using a pneumatic system [19].

Unlike wheat flour, Maize flours are difficult to fortify with iron. For instance lime-treated (nixtamalized) corn masa, a staple used to maketortillas in much of Latin America, goes rancid when soluble iron compounds, such as ferrous sulfate, are added to it and colour and texture changes occur during the preparation of tortillas. The difficulties are further compounded by the fact that iron absorption from corn masa is strongly inhibited by its high phytate and high calcium content. For these reasons, iron fortification of maize flours has not been widely adopted, except in a number of Latin American countries where the consumption of maize is high. In Venezuela, for example, ferrous fumarate mixed with elemental iron is used to fortify maize flours [3].

Cereal-Based Complementary Foods: Iron fortified with complementary foods has great potential in a critical time during growth and brain development of infants due to its contribution in iron requirement. Complementary foods usually prepared as a cereal based and consumed as a porridge or gruel with milk or water. Alternatively, they are based on blends of cereals and legumes, which again can be made into a porridge or gruel with water [3].

Two major technical constraints exist when cereals are selected as vehicles. One is due to its high levels of phytic acid and second due to the extreme sensitivity of unsaturated fat to oxidation during storage in the presence of highly reactive forms of iron (ferrous sulfate or fumarate). One option for increasing absorption is to hydrolyze the phytic acid in cereals, but nearly all of it needs to be removed. Initiation of natural phytases from legumes and some cereals (rye, buckwheat, and wheat) helps to hydrolyze phytic acid. Elemental iron powders which are not very reactive, usually used to fortify infant cereals, but they have extremely poor bioavailability and should not be used in complementary foods. The presence of inhibitors and enhancers should be critically assessed to ensure bioavailability. EDTA and ascorbate act as enhancers and have additive effects. For the selection of fortificant for specific complementary foods bioavailability studies are crucial but do not ensure effectiveness of the fortified food product. Compatibility and bioavailability within the specific food matrix should be considered for the choice of iron fortificant. Ferrous sulfate, fumarate and electrolytic iron are the better choices, provided that the food matrix, packaging and storage conditions are compatible for shelf life [18].

Condiments and Sauces: Condiments and sauces have several advantages as vehicles for iron fortification. In most countries, traditionally they are served as part of the daily diet, widely consumed, reach vulnerable populations, can be added to multiple foods and can be combined with fortified staple foods. In a place where central processing of staple food is limited, fortification of iron with condiments can provide a significant contribution. However, rich experiences of fortified condiments widely exploited around the globe: curry powder fortified with NaFeEDTA, sugar with NaFeEDTA, salt fortified with ferric orthophosphate, ferrous fumarate, sulfate, or bisglycine chelate, soy sauce and fish sauce fortified with NaFeEDTA and seasoning in noodles with ferrous sulfate [18].

Dairy products: Dairy products also can be used as a vehicle for iron fortification to combat iron deficiency disorder within the vulnerable groups. Thus, dried whole milk powders and dried or ready-to-feed milk-based infant formulas can be successfully fortified with ferrous sulfate (together with ascorbic acid to enhance absorption). Report showed that in Chile, for instance, ascorbic acid (700mg/kg) and iron (100mg as ferrous sulfate/kg) are routinely added to infant dried milk powders. However, ferrous sulfate is encapsulated with maltodextrin in soy formulas in order to prevent unwanted colour changes (i.e. darkening). Ferrous sulfate, and many other soluble iron compounds, cannot be used to fortify liquid whole milk and other dairy products because they cause rancidity and off-flavours. Ferric ammonium citrate, ferrous bisglycinate and micronized ferric pyrophosphate are generally more suitable for this purpose. Iron fortificants are best added after the milk has been homogenized and the fat internalized in micelles, so as to help protect against oxidation. Ferrous bisglycinate is widely used to fortify whole milk and dairy products in Brazil and Italy; micronized ferric pyrophosphate is added to dairy products in Japan [3].

Zinc: Zinc is an essential component of a large number of enzymes, and plays a central role in cellular growth and differentiation in tissues that have a rapid differentiation and turnover, including those of the immune system and those in the gastrointestinal tract. Zinc deficiency is likely to be a significant public health problem, especially in developing countries due to its supplementation positive impact on the growth of some stunted children, and the prevalence of some childhood diseases such as diarrhoea. However, the extent of zinc deficiency worldwide is not well documented. Study showed that all age groups of the population are at risk of zinc deficiency, but infants and young children are probably the most vulnerable. Pregnant and lactating women are also likely to be very susceptible to zinc deficiency, and there is an urgent need for more information on the implications of low zinc status in these particular population groups [3].

Zinc is an essential trace element in humans and known to serve as the active center for about 300 enzymes. It has been reported that the amount of zinc ingested per day may be insufficient relative to the daily requirement in some groups of individuals (children, elderly people, young women on weight-reducing diets, and some other groups). These individuals may develop quasi-deficiency or true deficiency of zinc [20].

Prevalence of Deficiency: The global prevalence of zinc is uncertain due to the lack of reliable and widely accepted indicators for zinc deficiency in the human body. The known indicators that are available, such as zinc concentration in plasma and hair, detect changes in zinc status only in cases of severe deficiency, and may fail to detect marginal deficiency. Even if it has no reliable indicator for zinc deficiency there are, however, several good reasons to suspect that zinc deficiency is common, especially in infants and children. Firstly, a high prevalence of low plasma zinc has been observed in some population groups, which is a reasonable indicator of relatively severe depletion. Secondly, several randomized control trials have demonstrated that stunted children, and/or those with low plasma zinc, respond positively to zinc supplementation, a finding suggests that zinc deficiency was a limiting factor in their growth. Growth stunting affects about a third of children in poor regions of the world where diets are of poor quality. This is not to say that zinc deficiency affects up to one third of children in the developing world since zinc deficiency is only but one of several possible causes of growth stunting [3].

Cell division, protein synthesis, and growth are the central roles of zinc. Thus, Zinc is very crucial for infants, children, adolescents, and pregnant women mostly affected by inadequate zinc intake. Several studies have been identified Zinc-responsive stunting in children; for example, a more rapid body weight gain in malnourished children from Bangladesh supplemented with zinc was reported. However, other studies have failed to show a growth promoting effect of zinc supplementation. Meta-analysis studies in zinc supplementation of 25 intervention trials comprising 1834 children less than 13 years of age, with a mean duration of approximately 7 months and a mean dose of zinc of 14mg/day (214mmol/day), showed a small but significant positive effect of zinc supplementation on height and weight increases. Zinc supplementation had a positive effect when stunting was initially present; a more pronounced effect on weight gain was associated with initial low plasma zinc concentrations [11].

Results from zinc supplementation studies indicated that children with low zinc status are susceptible to an increased risk of severe infectious diseases in addition to growth retardation. Episodes of acute diarrhea were characterized by shorter duration and less severity in zinc-supplemented groups; reductions in incidence of diarrhoea were also reported. While other studies suggested that zinc supplementation may reduce the incidence of acute lower respiratory tract infections and malaria. Prevention of suboptimal zinc status and zinc deficiency in children by an increased intake and availability of zinc could consequently have a significant effect on child health in developing countries [11].

Risk Factors for Deficiency

The causes of zinc deficiency fall under two main categories thus are nutritional causes such as consumption of food items with either low zinc contents or unavailable forms of zinc, and conditioned (secondary) deficiency related to diseases and genetic malfunctions that impair intestinal absorption and/or increase intestinal loss of zinc [21]. Zinc plays an important role in cell division, protein synthesis and growth, which means an adequate supply is especially important for infants, and pregnant and lactating women. Therefore, the principal risk factors for zinc deficiency include diets low in zinc or high in phytates, malabsorption disorders (including the presence of intestinal parasites and diarrhoea), impaired utilization of zinc and genetic diseases (e. g. acrodermatitis enteropathica, sickle-cell anaemia [3].

Choice of zinc fortificant

Selection of the appropriate zinc fortificant for a particular food item is very important during fortification of food with zinc. Zinc compounds that are suitable for use as food fortificants include the sulfate, chloride, gluconate, oxide and the stearate. All of these compounds are either white or colourless, but have varying water solubilities; some have an unpleasant taste when added to certain foods. Although it is only poorly water soluble, zinc oxide is the cheapest of the zinc fortificants and therefore tends to be the preferred choice. As reported by Dary & Hurrell [3], recent studies have shown that the absorption of zinc from cereal products fortified with zinc oxide is as good as that from those fortified with the more soluble zinc sulfate, presumably because the oxide is soluble in gastric acid. However, individuals with low stomach acid secretion may be poor in zinc absorption from the oxide.

The Bioavailability of Zinc

Zinc absorption from food is dependent on the amount of zinc consumed and the ratio of phytate to zinc in the meal being consumed. According to recent estimates by the International Zinc Nutrition Consultative Group (IZiNCG), when zinc intake is just adequate to meet the physiological requirements for absorbed zinc, in adult men about 27% of the zinc content is absorbed from diets having a phytate: zinc molar ratio of less than 18, which drops to about 19% when the phytate: zinc molar ratio is greater than 18 (i. e. high phytate). The corresponding zinc absorption rates for adult women are 35% and 26%, respectively. When zinc intake is greater than the critical level needed to meet requirements, the fractional absorption becomes progressively less, although the net absorption of zinc increases slightly. In one study involving healthy, well-nourished adults from the United States, zinc absorption from the sulfate (or the oxide) added to a low-phytate bread meal was about 14% (total zinc content, 3. 1–3. 7mg per meal) compared with around 6% from the same fortificants added to a high-phytate wheat porridge meal (total zinc content, 2. 7–3. 1mg per meal) [3].

Zinc Fortified Foods

Fortification food with zinc has been fairly limited, and is generally confined to infant formula milks (with zinc sulfate); complementary foods and ready-to-eat breakfast cereals (in the United States). However, in Indonesia for instance it is obligatory practice to add zinc to wheat noodles. More recently, several Latin American countries have expressed some interest in fortifying cereal flours with zinc. Several studies have demonstrated the benefits of zinc supplementation on the growth rate of children. However, very few trials have assessed the efficacy or effectiveness of zinc fortification. Although the addition of zinc oxide to breakfast cereals increased plasma zinc concentrations in preschool- aged children in the United States, there was no evidence of concomitant increases in growth rates or in food intake. However, in Turkey, zinc fortification of bread did increase the growth rates of schoolchildren who initially had low plasma zinc. Little is known about the effects of added zinc on the sensory properties of foods. The fortification of wheat flour with relatively high levels of zinc (as zinc acetate) did not affect the baking or organoleptic properties of the bread dough. Likewise, the addition of 60 or 100 mg zinc/kg wheat flour (as zinc sulfate or zinc oxide) did not change the acceptability of bread [3].

Conclusion

As a conclusion, micronutrients are required in small amounts for the normal functioning of our body. Consumption of a limited or excess amount of micronutrient with diet causes serious health effects to human beings. Specially, micronutrient deficiency results in many health risks including goiter, blindness, anemia, cognitive impairments, impaired work capacity and maternal mortality. Nowadays, micronutrients deficiency affects people living all over the world but the prevalence of micronutrients is high in low income countries, including Ethiopia. Among the several essential micronutrients, the prevalence of vitamin A, iodine, and iron are high throughout the world especially in developing countries. Hence, mostly they affect preschool-children, school children, adolescent, pregnant and lactating women. Currently, the prevalence of zinc deficiency is also well recognized and which affects mostly children and infants around the world.

The main causes of micronutrient deficiency are nutritional causes such as consumption of food items with either low micronutrient contents or unavailable forms of micronutrients, and conditioned (secondary) deficiency related to diseases and genetic malfunctions that impair intestinal absorption and/or increase intestinal loss of micronutrients. Different micronutrient deficiency intervention mechanisms have been practiced around the world like, food supplementation, dietary diversification, nutrition education, public health and food safety measurement and finally food fortification. Among food based intervention mechanisms, food fortification is found to be the best effective means of intervention to reach the most vulnerable group throughout the continent, especially for people who are living in developing countries having low income. In general, food fortification can knock the door of every society, if it is implemented in such way that includes all people having different level of economic status by fortifying appropriate foods for each community and targeted groups in order to meet their dietary requirements to alleviate micronutrient deficiency because food fortification encompasses or intended to include all groups of the people who are living around the globe, especially to those vulnerable groups who are living in developing countries.

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