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Review on food matrix –fortificants interaction, implication, bioavailability and costs

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Abstract
Nutrition is a very important component for the development of health which improves the physical and cognitive abilities of infants and young children. However, deficiencies of micronutrients have significant impacts on infants and young children's growth development. Fortification is a cost-effective scheme with proven health, economic and social benefits. It is probable to be more cost-effective, and a very essential mechanism of public health approaches used for enhancements of nutritional values of supplementary foods, micronutrients such as vitamins, and minerals which have a crucial in preventing child mortality. The common food micronutrient elements used for fortification purposes include milk, Iron, Zinc, Iodine, and vitamin A, and folate which are globally the most serious health risk factors. However, the interaction between micronutrients affects absorption and the bio availabilities of nutrients used for food fortification programs. And, the nature and physicochemical properties of substances lead to interferences such as antagonism and synergism between nutrients such as drug and micronutrients is physicochemical interaction that the losses of the chelating cause of nutrients which reduces the activity of the drug. Minerals of iron and Zinc have characteristics of competition with one another and this causes interferences with absorptions. Factors for fortification giving consideration are the cost of the fortificants, capital, blending, and transportation mechanisms; other factors which are a source of variations for fortification include technological aspects and varieties of raw materials, and their costs. Developing countries particularly Ethiopia, not only the limitation of categorizing staple foods used for food fortification, and also basic experiences on factories working on flour-based products, which are considered as drawbacks for the country to initiate fortification. Fortificants (wheat, sugar, and edible oil) are concentrated with the highest income divisions, which leads that the Ethiopian poorest nation covers 20% of 5.4 million Anemia cases.

Key words: Food matrix, fortificants, bioavailability, implication, malnutrition, and costs

1. Introduction
Nutrition is a very important part of the development of healthy and productivity, which improves physical and cognitive development and inhibits disease for societies. Organic and inorganic micronutrient deficiencies are wide blowout with underdeveloped countries.

Fortification of food is a very important public health approach and it has the advantage of accomplishing broader population groups found at-risk through existing food delivery systems, without requiring major changes in the existing consumption patterns **[1, 2].** Food fortification has a long history of use in industrialized countries for the successful control of deficiencies of organic micronutrients such as vitamins A and D, several B vitamins, and inorganic micronutrient includes iodine, Zinc, and the mineral concentration of iron. The implications of micronutrient deficiencies are not limited to health parameters only but have beyond effects on economies through secondary physical and mental disabilities and can change work productivity. Several strategies have been engaged to enhance micronutrients to women and children **[2, 3],** and these include education, dietary modification, food rationing, supplementation, and fortification. Food fortification is one of the policies used carefully and efficiently to avoid micronutrient deficiencies and has been practiced in developed countries for well over a century now. Although the effectiveness ratio of fortification depends on local conditions and deficiency fashions, resources, food vehicles, and fortificants used, and it is generally recognized as one of the most cost-effective interventions used to improve the existed foods with less in macro and micronutrients. Horton et al **[4]** estimated that the advantage: cost ratio of iron fortification in 10 countries with high levels of anemia is 8.7:1. For iodization of salt, a benefit-cost ratio of around 70:1 **[5]** is demonstrated, while for folic acid a range lengthy from 11.8:1 for Chile to 30:1 in South Africa. Nutrient stability in fortified products is reliant on many factors including the fortification process, the cooperating nature of the micronutrients, a storage system of the product, and processing approaches associated with different situations **[4, 5].** Due to the chemical and physical nature of the raw materials, macro and micronutrient availabilities of fortified foods are significantly affected. Generally, peoples who are most susceptible to these micronutrient deficiencies are pregnant and lactating women and young children, given their increased demands **[6, 7].**

Food fortification is a cost-effective approach with proved health, economic and social benefits. Despite the discussions globally and in some countries about the status and safety of food fortification, the practice attempts significant benefits across each of the main vehicles for food fortification extending from reducing the occurrence of nutritional deficiencies and economic benefits to societies. Due to the chemical and physical nature of the raw materials, macro and micronutrient availabilities of fortified foods are significantly affected. Generally, people who are most susceptible to these micronutrient deficiencies are pregnant and lactating women and young children, given their increased demands **[6, 7].** Therefore, the main objective of this

review article includes reviewing the effects of food matrix-fortificants interaction and bioavailability's of minerals, how fortificants interferences reduce the bioavailability of nutrients, cost effects of food fortificants with globally selected micronutrients, and summarize mineral interaction and food fortification associated with malnutrition, particularly in Ethiopia.

2. Methodology

For this review article, those different sources of materials of kinds of literature such as journal articles, books, documents of different workshops, and proceedings facts were used. And FAO reports, different research articles including research on guidelines on food fortification and formulations, research experiences, and observations. And in addition to this, the sources were gathered from unpublished M.Sc. thesis and doctoral dissertations, and documents were gathered from internet access, research institutions, and individual researchers including seminar workshops.

2.1. Food fortification

Effective nursing performs at the early stages of life have a positive influence on the growth and development of a child, that infants with limited feeding practices lead to retardations of growth and development **[8, 9].** As different studies reported that, the growth hindrance in infants can happen at the time of birth and this can be increased through eighteen months **[10, 11].** However, the strategy which is called food fortification creates positive occasions to improve the limitations of nutrients that are necessarily intakes during infancy which have a significant effect on the growth and development of children **[12].** Applicable of the food vehicles are the major important factors for food fortification that supplementary feeding strategies depend on.

Food fortification is defined as the practice of purposefully increasing the content of vital micronutrients (vitamins and minerals and trace elements) **[13],** which play a role to improve the nutritional quality of the food source and delivering a public health benefit with negligible risk to wellbeing. On the other hand, fortification differs from enhancement, which is the process of reestablishing the nutrients to a portion of food that are removed during the manufacturing of the food. Fortification is one of the very important public health interventions towards alleviating micronutrient starvation of infants and young children **[14].** In addition to this, studies reported that fortification confirmed better efficiency as compared with food supplementations for infants and young children **[15].** Strategies with food fortification involving the addition of micronutrients are designed to reduce deficiencies within defined populations. World Health Organization (WHO) sorts food fortification schemes into three potential methods: includes mass, targeted, and market determinants **[16].** Mass fortification involves foods that are widely consumed, such as wheat, salt, sugar; targeted approaches fortify foods consumed by specific age

groups like infant complementary foods, and the market-force approach is when a food producer fortifies a specific brand for a particular consumer function. On the other hand, food vehicles commonly used can be grouped into three broad categories: staples (wheat, rice, oils), flavor source foods (salt, soy sauce, sugar), and processed marketable foods (noodles, infant complementary foods, dairy products).

Similarly, another study through making a test on the effects of milk fortified with iodine on the intellectual ability of children, where a substantial promising influence was realized on the mental function of school children **[17].** This relationship is not far from the truth as iodine is needed for the production of thyroid hormone that is essential for growth.

3.2. Food fortificants

In the world, there are different countries that are under development that used different food matrixes or different commodities for food fortification purposes to solve malnutrition which retards the growth and development of children including mental cognitive abilities. Different studies are conducted on the effects of milk, Iodine, and etc as fortificants and stated that there have been significant contributions on malnutrition. **[18],** reported that, within fitting units in a normal diet, fortified milk is an effective source of balancing nourishment to complement infants and young children, while **[19],** reported that, multiple micronutrient milk beverages have an inclusive improvement in the mental and physical performance of school children. In addition to this, **[20, 21],** reported that, micronutrient fortification with n-3 fatty acids and vitamin A-fortified monosodium glutamate have a better linear growth as compared with low micronutrient fortified diets, linear growth among children, respectively. Studies reported that, food fortification reduces the prevalence of micronutrient deficiencies, and can be enhanced the health status of infants and young children **[22].** On the other hand, WHO **[23],** stated that, Iron, Vitamin A, Zinc, and Iodine deficiencies are the globally the most serious health risk factors, and to discourse the micronutrient deficiencies, food fortification is one of the four strategies used as a basic tool to solve micronutrients limitations which leads to malnutrition. In general, instantaneous or cooked infant and young children fortified foods include fortified blend food; there are three fortified products that may be cooked or instantaneous including, complimentary food supplements, and micronutrient powder, which is used as a point of –fortificants **[24].**

3.3. Food matrix - fortificants interaction

3.3.1. Interactions of micronutrients

Now a day, health professionals are annoying to develop an approach to provide multi-nutrient complements having a better nutrient which can improve the diet includes vitamins such as vitamin A and folate, minerals such as Iron and Zinc **[25].** Possible risk of interactions between

micronutrients affecting absorption and bioavailability of nutrients used in any supplementation or food fortification programs. The nature of similarity of physicochemical substances leads to interaction effects such as antagonism and synergic affects between chemicals such micronutrients which reduces the activities rates of the nutrients. One example of interactions between drug and micronutrients is physicochemical interaction, which is represented by chelating causing the loss of nutrients and this reduced the activities of the drug **[26].** On the other hand, excess amounts of supplements can have health adverse effects, in which nutrients themselves become toxic to the body such as vitamin A **[27].** In addition to this, Sandstrom, **[28]** reported that, micronutrients such as Iron and Zinc have the characteristics of competition with one another and this becomes the cause for the interferences with absorptions.

If both minerals of iron and zinc are giving simultaneously, it is vital to regulate how they interrelate biologically. Because of the Physico-chemical nature associated with absorption and transport mechanisms, minerals such as Iron and Zinc have been supposed to strive for absorptive paths **[29].** There is a study on cell culture which indicated that, mineral iron may constrain zinc absorption in some cells at very high ratios of iron to zinc, and the study stated that the inverse is not true **[30].** The extensive use of Iron fortification and supplementation makes any interface among iron and other micronutrients which have very important nutritional relevance.

3.3.2. Bioavailability of fortified foods

Bioavailability of foods can be defined as the quantity or segment of a nutrient in the diet that is eventually available for use or storage in the body after digestion, absorption, and distribution **[31].** Bio-accessibility is the fraction of ingested nutrient which is released from the food matrix and made available for absorption in the gut **[29].** The food matrix contains other elements that may bind to which going to change the chemical structure of the nutrient and it will influence the absorption of the capacities. As an example, phytate chelates metal ions from fortified foods, such as iron and zinc, forming insoluble complexes in the gastrointestinal tract **[32].** The human gastrointestinal tract lacks phytate activity and therefore the phytate-bound minerals will be extracted in the stool. In addition to phytic acid from cereals, polyphenols from chocolate drinks and calcium and casein from dairy also chelate iron and zinc minerals **[33].** On the other hand, the bioavailability of vitamins added to foods is the same as originally present foods and in addition to carotenoids Iron and also needs great attention. The bioavailability of minerals such as Iron depends on different factors; for example, for reduced Iron, the mesh size is a very

important factor indicated that mesh size with the biggest size is un-recommended **[34].**

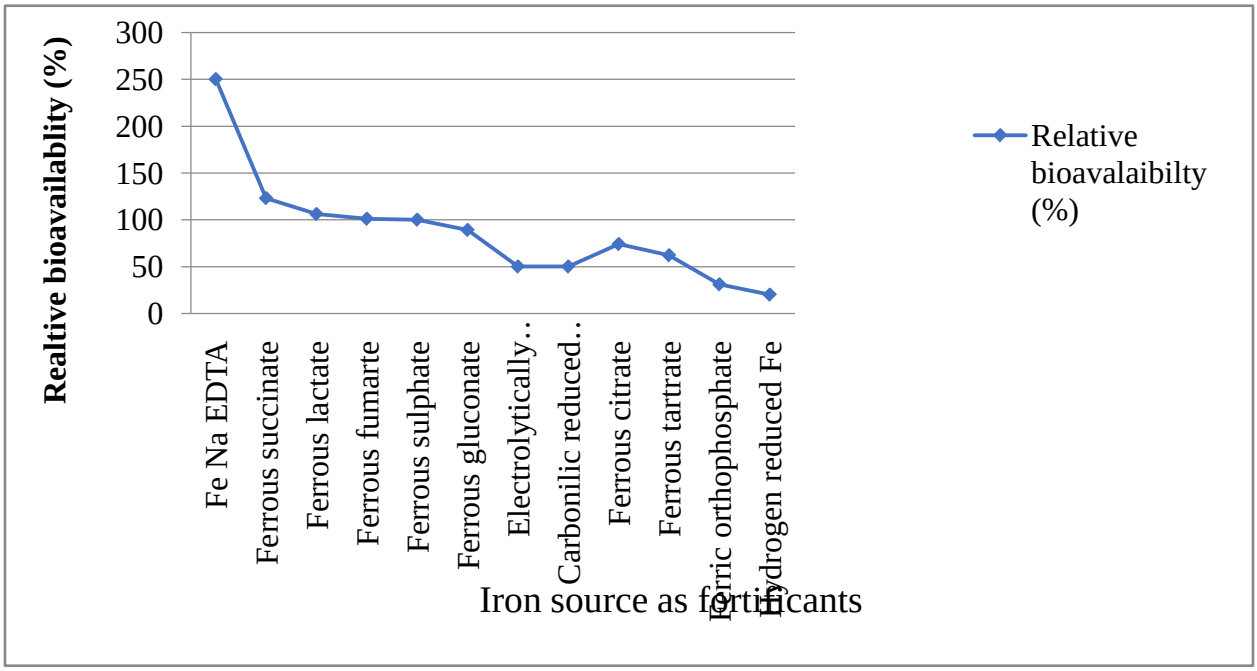

Figure: Relative bioavailability of iron salts used as fortificants **[35, 36, 37].**

4. Cost effectiveness and accessibility of commonly fortificants foods

Eradicating micronutrient deficits can have the greatest intangible social and economic benefits; which help to reduce the significant effects on the reductions of cognitive ability, growth, and development of the infant and young children, and this leads or becomes the basic causes for the death of pregnancy and child. This implies that food fortification is the best mechanism to eliminate such challenges being it is cost-effective as compared with supplementations and home gardening **[34].** The cost-effectiveness of food fortification has played a significant role in public policy application. An important source of reliable estimates for the economy of micronutrient involvements is the World Health Organization - select or indicating interventions that are cost-effective **[38].** These assessments are not directly obtained from interventions; rather they are constructed from what is known about the cost of interventions, effectiveness that may be interferences of micronutrient status of interventions, and relations between micronutrient status and disease or death outcomes. Food fortification is assuming a sustainable public health strategy due to reason that it can influence a wider range of the populations which may be found at risk and existing food distribution systems without needing major changes in current feeding patterns **[39].** Compared to other interventions, food fortification is probable to be more cost-effective, and – if fortified foods are repeatedly consumed – it has the advantage of maintaining steady body stores **[40].** The usefulness of food fortification has been confirmed consistently and is now largely accepted **[31, 41].** Recent systematic reviews suggest that micronutrient fortification of

foods has the potential to significantly increase serum micronutrient concentrations and reduce deficiencies **[29, 42].** World Health Organization, World Bank, and UNICEF **[22],** reported that, food fortification is the most cost-effective mechanism for better health intervention, and is one of the basic approaches for developing countries as improvements through primary food fortification.

During fortifications of supplementary staple foods, there are factors giving considerations to assess the ways of cost-effectiveness including the cost of the fortificants (raw materials used as staple foods), the capital, and the tasks used for blending, and costs used for transportations mechanisms and used for quality assurance systems. World Bank **[43],** reported that, relative to the degree of fortification, and the technological aspects, the variety of food which going to be fortified is varied its costs of fortification. And, **[43],** stated that it estimated the cost less than US$1 to reduce shortages of Vitamin A, and mineral concentration including Zinc and Iron per year.

5. Malnutrition and food fortification status in Ethiopia

Food security is a major concern in countries like Sub-Saharan Africa (SSA), particularly in Ethiopia. Ethiopia is the second most populated country having rapid population growth with increasing rates of malnutrition which results from the interaction between poor diet and disease among children in the country (http://faostat.fao.org/). Agriculture is the pillar of the Ethiopian economy and it is the source of 64% of calories consumed **[44]**. This implies that the dietary diversity of the country depends on cereal crops, which are micronutrient deficiencies. However, in the country foods are quantitatively insufficient and supplied with a lack of diversity and the dietary energy supply is not sufficient to meet the energy requirements and almost half of the population is undernourished. Therefore, providing adequate food for a rapidly increasing population becomes one of the greatest challenges in the country. The report from WHO in 2013 revealed that, the first 1000 days have a great role in a child's brain and cognitive development, immune system, and growth. Ethiopia Demographic and Health Survey (DHS) reported that the occurrence of stunted (37%), wasted (7%), and underweight (21%) are issues of great concern, respectively **[45].** However, 71.8% of mothers are inaccessible for complementary foods in Ethiopia. On the other hand, in Ethiopia, all the complementary foods prepared from cereal crops are deficiencies in micronutrients. Therefore, nutrient-dense complementary feeding improvement should be of the highest priority for infants and young children because of its crucial role in preventing mortality and enhancing children's development in the country. Formulation and development of nutritious weaning foods from local and readily available raw materials has received a lot of attention in many developing countries such as Ethiopia. Now a

day Ethiopian government works on the areas of implementation of malnutrition policy and it undertaking initiatives to eliminate all forms of malnutrition by 2030; which includes stated the Sensitive Agriculture policy, the National Nutrition Programme (NNPI and NNP II), and Seqota, and the newly implemented National Nutrition Policy and Strategy.

On the other hand, the reason those in Ethiopia there are limitations of categorizing staple foods used which are widely consumed in the country and as industrially processed foods [46]. These deficiencies of basic information may become a drawback to initiate fortification in the country, and no major staple foods are fortified **[47],** this is highly associated with the deficiencies of industries or factories working on flour based products in the country. As **[48],** reported that, for food fortification concepts, based on the low coverages and high costs, currently sugar fortification with vitamin A is not recommended. On the other hand, the edible palm oil (87%) imported from Asia, is sufficient to fortify it, and this is because 55% of the population purchased it on the average per capita consumption at about 15 grams per day **[48],** it is estimated that if it is fortified with vitamin A that can supply 47% and 35% recommended nutrition intake of adult women and young children, respectively in Ethiopia. However, with the collaboration of national nutrition strategy associated with national micronutrient guidelines established by the ministry of health (MOH), developed a framework or approaches to diminish micronutrient deficiencies problem such as food fortifications in the country **[48].** In Ethiopia, the three food fortificants, (wheat flour, sugar, and edible oil) are mostly associated with the highest income divisions. This cause a severe situation's such as micronutrient deficiencies which lead a significant public risk such as the lowest income, and this leads that Ethiopian poorest nation covers 20% of 5.4 million Anemia cases **[48].**

Conclusion

Due to the reason food fortificants Physico-chemical properties and coopetition interface, the bio-availabilities of nutrients are affected from the food matrix. Since the nutritional availability of fortified foods is deepens upon the interaction of the food matrix with food fortificants, the presence of a non-nutrient substance in the food matrix reacts with fortificants reduces the availability of the micronutrients. Therefore, non-nutrient substances and micronutrients having the capacity of impairing of other nutrients should be determined and make accurate proportion before fortification have been performed. However, income status, technology, fortificants variation, and costs are factors that affect fortification. In Ethiopia, 71.8% of mothers are inaccessible for complementary foods, the prevalence with stunted (37%), wasted (7%), and underweight (21%) are issues of great concern, respectively. And, it needs a great deal with the

developments of industries working with flour for fortification which may solve these of malnutrition prevalence.

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