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Iron fortification in foods and its absorption: A review

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Abstract
The consequences of deficient of iron intake could be more dangerous than low energy diet in regular intake and it can cause anemia. The treatment of anemia is based on iron supplementation or by iron fortification in flour, bread and cereals, as these are the staple food. Fortification is the enrichment of the micronutrients in the food to overcome the deficiency. Iron fortification is a suitable strategy and long term goal to increase the iron intake. Controlling the iron deficiency anemia also depends on the enhanced gastrointestinal iron absorption and minimum quantity of iron absorption inhibitors. *In vitro* is the mimic of gastrointestinal digestion of human and provides important characterized strain data which is useful precursors to *in vivo* studies. This review article gives emphasis on major effect and application of iron fortified food to overcome iron deficient anemia.

Keywords: Food fortification, Iron deficient anemia, Iron absorption enhancers, Iron absorption inhibitors

1. Introduction
Anemia is a deficiency caused by a diet lacking the iron, which is a public health issue. It is the most widespread and common disorder in the world both in developed as well as in developing countries, which affects 1.62 billion individuals globally [1]. 20-50% of the world's population is believed to be affected by iron deficiency which is the most worldwide disorder [10]. Around 50% population of new born, children and women of fertile age is suffering from iron deficiency mostly in some parts of Africa, south Asia and Latin America [2].
Iron is an essential nutrient needed for hemoglobin, red blood cell synthesis [3], oxygen transport throughout the body and also prevents from iron deficiency anemia [4]. Iron deficiency affects all the groups of people, such as delayed cognitive function in infants, malnourished adolescence and adults [3], an adverse outcome during pregnancy, increased risk of premature birth and problem with immune system [5]. It negatively affects in health, education, economic and productive development [6]. It is characterized by fatigue, weakness, pallor and reduced capacity of blood to deliver oxygen to body cells and tissue [7]. Treatment for anemia is based on dietary recommendations and oral iron supplements [3]. Fortification of staple foods is also a feasible solution that can be used to enhance the intake and overcome from iron deficiency [10].
Food fortification is defined as the addition of various components, without requiring major changes in existing consumption pattern [11]. Fortification is an important approach for the increase in iron intake and reductions in iron deficiency anemia in US. In 1941 fortification came into existence when cereal-grain products were made with iron fortified flour [12]. Consequently, several countries have established programs to fortify flour with iron [10]. To provide the level of fortification approximately 20–40% of the daily requirement intakes has been studied through newly designed food products. With a single fortified product the requirement of iron should be less than the maximum iron level [13].

1.1 Iron from foods
Iron is present in foods in 2 forms: haem iron is animal based diet, which helps to absorb 15-25%, and non-haem is plant based and ornimal based diet such as milk and egg, it absorbs only 5% [4]. Haem iron breaks by intestinal cells and gets easily absorbed [8]. The urge of iron could be meet by consuming foods that provide a well-balanced, iron dense diet. Some of the iron dietary sources in foods are given in the Table 1.

Table 1: Primary sources of dietary iron [4].

Samples	Amount	Iron content (mg)
Sausage	1 slice	18
Turmeric	160 g	1.8
Liver	90 g	5.2–9.9
Coconut milk	1 1/2 cups	4.3
Soy beans	1/2 cup	4.2
Spinach	1 cup	3.2
Lean beef	90 g	3.1
Duck	90 g	2.3
Red beans	1/2 cup	2.6

The food pattern depends on the culture, religion and geographic cultivars, such as plant based or animal based, therefore the dietary iron intake also varies accordingly. The level of recommended dietary iron values for the different countries depends on the genetic iron bioavailability. Most foods contain relatively low level of naturally occurring iron. To fulfill the recommended dietary intake of iron in regular diet, food fortification of the staple food is the strategy to overcome the iron deficiency. These fortified foods can raise the intake of iron without any changes in consumption habit. Food fortification is more cost effective approach than iron supplements. For fortification many iron compounds have been used to increase iron intake in staples (rice, wheat, corn) and processed commercial foods (bread, dairy, salt etc.) [6].

2. Iron fortification in foods

Ferrous sulphate is mostly used to fortify the infant formulas and cereal flour, which can be stored only for short periods. Ferrous gluconate, ferrous lactate, and ferric ammonium citrate are the other major fortificants. Sodium iron EDTA (NaFeEDTA) is the often-used non-haem source used for the better iron absorption and which can inhibit the effects of anti-nutritional properties [21]. Ferric pyrophosphate and ferric orthophosphate are the most frequently-used compounds which are poorly soluble in acids but they have different absorption because it is not easily dissolved in gastric juice. Their main advantage is that they cause no organoleptic problems [7]. Folic acid also has been used for the fortification of cereal flours, noodles, rice and various sauces [7]. The other vehicles for iron fortification have been used, such as dairy products, sugar, curry powder, soya sauce, salt, margarine and cookies. However, cereals are the most widely used vehicles for iron fortification [23].

As wheat is the staple food, which is consumed by the large population for the preparation of baking products, while approximately 90% of the wheat flour in India is consumed in the form of chapatti (unleavened bread) [15]. According to a survey on wheat cultivars grown in different climatic conditions there is a variation between the iron content of different genotypes [16]. So, with the fortification of the wheat flour worldwide in commercial milling is a helpful strategy to bring the iron deficiency under control in low cost [17]. The level of iron to be added has been released in 2009 by the World Health Organization (WHO). In a study the recommended iron and wheat flour was varied in different iron compounds at different levels to examine if there are any adverse interactions. Then unleavened bread were prepared and investigated by academic sensory analysis. Results showed that, there are no changes in the properties after baking and cooking when the levels of iron elements varied [18]. In another study various elemental irons have been used for cereal flour. They have focused on the advantage of adding the elemental iron, they have found that there are very few problems in color and flavor, they are inexpensive and suitable for wheat and maize fortification [22].

Another investigation was done to produce gluten-free bread (GFB-Fe) which was fortified with iron. They have used different elemental iron, such as ferric pyrophosphate, ferric pyrophosphate with emulsifiers, electrolytic iron, ferrous gluconate, ferrous lactate and ferrous sulphate. They have found that the products made up of ferric pyrophosphate with emulsifiers were the most acceptable [19]. In another investigation, the flat breads of fortified wheat flour have been made using ferrous sulphate and sodium iron Ethylenediaminetetraacetic acid (NaFeEDTA). The iron fortified breads were similar to non fortified regular bread in sensory analysis. It showed that the formulated flour contain NaFeEDTA iron was 25% increments lower than the visual detection approach than ferrous sulphate. It was concluded that, it can be used on regular basis for the iron deficiency anemia specifically for the women in childbearing age [20].

Rice is also a staple food which is consumed > 440 million MT/ year but there is no sufficient fortified rice available. So, there is an opportunity to fortify rice. In a review literature, rice fortification was compared with other fortified staple foods. They have found that most fortified rice were first fortified the kernel and then blend it with normal rice. The kernel fortification requires investment and production cost and can be implemented only by the large rice mill industries [14].

Apart from the above mentioned elemental iron, a study has been done for natural fortificat. In this study they have used black cumin (BC) (Nigella sativa) defatted meal and it was added to whole wheat flour (WWF) to flat bread formulation to deliver daily intake of iron. They have concluded that, by consuming one piece of this bread, one can receive the recommended daily allowance of iron [24].

3. Iron absorption enhancer and inhibitor

Cereals and plant foods contain high amount of anti-nutritional properties such as, phytic acid and polyphenolics which is an iron-binding compounds, it also inhibits the absorption of iron and causes iron deficiency in humans [25]. By removing inhibitors or fortifying with enhancers of iron in staple foods may be improve the iron bioavailability, such as rice, wheat, maize, sweet potato and cassava [26]. In this regard, certain dietary additives are needed to be studied widely, such as prebiotics and iron chelators [27]. In a study the *in vitro* effects of supplemental inulin to assess iron bioavailability have been examined. Yogurts, with and without inulin, were compared by an *in vitro* gastrointestinal digestion. Prebiotics have been shown to increase the iron absorption [28]. These prebiotics are not digestable in the upper digestive tract and passes to the lower gut for the fermentation by the microbes to get absorbed. The other possible enhancers are short-chain fructooligosaccharides, inulin and inulin-type fructans [26].

To overcome from iron deficiency the iron intake should reach the recommendation by enhancing the iron absorption. In a study three meat products were enriched with different iron, such as ferrous sulfate, ferric pyrophosphate which was encapsulated by liposomes and fed to iron deficient women. After six hours of having the iron enriched meat the blood samples were taken and serum iron was determined. It was found that there was increase in serum iron concentration by addition of meat in the diet [29]. One more investigation has

been done on pea and soybean, which was fortified with ascorbic acid and ferrous sulfate on the dialyzability of iron. The dialyzed iron was influenced by soybean which acted as alkaline and ascorbic acid in the role of acidifying. There was increase in iron dialyzability by ascorbic acid. It was also found that ferrous sulfate has the positive effect on iron dialyzability [30].

4. *In-vitro* and *in vivo* studies

In a study an investigation was done for the iron bioavailability on iron fortified bread. The enzymatic degradation of the phytates was done within gastro-intestinal digestion conditions *in vitro*. This study of iron bioavailability was performed *in vivo* on experimental rats. For the study of biochemical indices of the blood was collected from the rats. It showed that iron intake plays conclusive role in animal nutrition and iron was improved [4]. In another investigation, wheat flour fortification has been done with or without ascorbic acid to improve the absorption of iron. The unleavened bread was fortified with iron and bioavailability of iron was done by *in vitro* test. It has been found that ascorbic acid has enhanced the *in vitro* total iron bioavailability from iron fortified unleavened bread [31].

Due to iron deficiency of the high frequency of anemia, *in vivo* study has been done to investigate absorption of iron by intestine with the effects of prebiotics. Wistar rats were fed the iron deficient diets to induce iron deficiency anemia. Then, to allow recovery from anemia the iron compound was added to diets. It has been found that, the iron absorption in the intestine has increased in rats [23]. Another *in vivo* study was done in preschool children. They were fed with the fortified rolls. Fortification was done by sodium alginate microencapsulated with iron sulfate. It was given to investigate the hemoglobin level and compared to control. The initial hemoglobin was noted. They have found that there is increase in hemoglobin by the consumption of fortified rolls [32].

5. Conclusion

Food fortification is a great approach for overcoming of iron deficiency anemia. In developing countries staple food fortification can give benefits to poor population. Staple food will be also a beneficial perspective to increase the iron absorption and decrease the absorption inhibitor, which might be produce by the processors. In iron bioavailability approach, there is sufficient studies have been done for phytate and polyphenols regarding iron absorption inhibitors. During the last decade many investigations have been done for the iron absorption enhancers, such as prebiotic and probiotic as novel peptides. Finally, an integrated investigation is needed to overcome the iron deficiency anemia by producing iron fortified foods with enhanced bioavailability.

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