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RESEARCH ARTICLE

IRON FORTIFICATION ON DIFFERENT FOOD VEHICLE

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ABSTRACT

Food fortification is considered highly effective and flexible method, is socially acceptable and furthermore, it does not interfere with the population's dietary habits. In addition, the risk of side effects and toxicity are minimal due to reduced doses of micronutrients added to foods. Iron fortification is the most cost effective method of preventing iron deficiency anaemia. The food vehicle of choice must be consumed regularly and in large scale by the targeted population. The selected iron compound does not cause unacceptable changes in color and flavor when added to foods. Additionally, the food vehicle should be sufficiently stable during long periods of storage.

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INTRODUCTION

WHO has defined "*Food Fortification*" as "the process whereby nutrients are added to foods (in relatively small quantities) to maintain or improve the quality of the diet of a group, a community or a population" (WHO 1971). In other words *Fortification* as generally understood refers to the process of addition of a nutrient to a food to improve the quality or as e measure of delivering the nutrient to the population to correct the existing deficiency among them. While it is true that both "*Fortification*" and "*Enrichment*" refers to the addition of nutrients to the food, the true definitions do slightly vary. Enrichment is defined as "synonymous with fortification and refers to the addition of micronutrients to a food which are lost during processing." (www.google.com). Food Fortification was defined as the second strategy of four by the WHO and FAO to begin decreasing the incidence of nutrient deficiencies (3 common form of micronutrient malnutritions are iron deficiency, vitamin A deficiency and iodine deficiency) at the global level. Various foods like sugar, salt, margarine, wheat flour, bread, infant formula, biscuit, and milk are used as a vehicle for fortification in most of developing countries (Guidelines on food fortification with micronutrients, 2006). Here, the present study is concerned about iron fortification. According to review report of Huma et al. (July 3 2012) food fortification with iron can be effective to prevent iron deficiency anaemia.

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Over 1.6 billion people or a quarter of the world's population are anemic (Huma, 2012). The prevalence of anaemia is highest (47.4%) among preschool children but over 40% of pregnant women, 30% of non pregnant women, 25% school children are also affected (WHO/CDC 2008). Strategies for combating iron deficiency include control of parasitic infections, improvement of sanitation, iron supplementation and iron fortification. Of these strategies, iron fortification of basic foods is the most economical and more convenient approach and has the advantage i.e it does not require food habit modifications. There are some important steps for a fortification program to be successful. Two of the key issues are the food vehicle and the iron compound. The food vehicle selected should reach the entire population and deliver most of the calories of the diet. It has to be consumed daily but at the same time with no risk of excessive consumption. The selection of the iron compound for fortification is important in order to avoid interactions of iron with the food vehicle or the total meal, because a minor change in organoleptic characteristics of the food will result in consumers' rejection (Cook *et al.,* 1983) (Cook, 1983). Foods which are fortified with iron in developing countries generally are cereals like wheat flour, infant formula, rice, biscuit, sugar, salt, milk etc.

Aims and Objectives

- To identify and analyze iron fortification studies for their efficacy and effectiveness in India
- To prevent iron deficiency anaemia
- To prevent micronutrients malnutrition
- To restore the normal level of iron

DISCUSSION

Strategies for combating iron deficiency

Strategies for combating iron deficiency include control of parasitic infections, improvement of sanitation, iron supplementation and iron fortification. Of these strategies, iron fortification of basic foods is the most economical and more convenient approach and has the advantage that is does not require food habit modifications (Cook *et al*., 1983).

Iron fortification in various vehicles

Criteria for selection of Food Vehicles (World Health Organization, 2006):

- Food selected as vehicle for fortification should be consumed by a large proportion of the population, including (or especially) the population groups at greatest risk of deficiency.
- They are consumed on a regular basis, in adequate and relatively consistent
- amounts.
- They should be centrally processed.
- Unrelated to socio economic status
- The food selected doesnot seriously interfere with the utilisation of nutrient.
- Stable during storage and distribution.

Criteria for selection of nutrients

- The amount of nutrient added should not be toxic or harmful to the individual with high intake of fortified food.
- Should be well absorbed when taken with meal.
- Should not develop colour when mixed with the vehicles.
- Must not impart colour or taste to food.
- Stable during storage and transportation of fortified food.
- The method of controlling or enforcing the level of fortification should be available.

Iron fortification of orange juice

Almeida *et al*. in 2003 evaluated that iron fortification of orange juice which is rich in vitamin C, greatly facilitates iron absorption. An iron compound can be added during processing without provoking organoleptic changes (i.e., color, flavor, and consistency) (de Almeida, 2003).

Iron fortification of Mandioca Flour

According to the Tuma *et al* (2003), mandioca flour is widely consumed in the North region of the country and can be considered a promising food vehicle in the control and prevention of iron deficiency and anemia (Tuma, 2003).

Iron fortification of milk

According to Torres *et al*. (1995), the use of cow's milk, due to social economic and cultural practices, is used frequently in Latin America, including Brazil, during infancy, and iron fortification of this vehicle is an inexpensive alternative to increasing iron levels in children (Torres, 2000).

Iron fortification of casein micelles

Sana Raouche *et al*. in 2009 used casein micelles as a vehicles for iron fortification. Their study showed that Iron-fortified milk samples were stable under heating, except when fortification was achieved by means of 20 mmol kg^{-1} ferric chloride. The most obvious difference of iron-fortified milk is its appearance: samples fortified with ferrous chloride were darker than control, whereas samples fortified with ferric chloride were more red/yellow (Sana Rouche, 2009).

Iron fortification of Milk based Cornstarch Porridge: 4 years old preschoolers (n=131) was studied with control in 2012 by Francisco Plácido Nogueira Arcanjo *et al*. to evaluate the impact of a milk-based cornstarch porridge fortified with iron on hemoglobin levels and anemia prevalence .This study showed that milk-based cornstarch porridge fortified with ferrous sulfate increased hemoglobin levels and reduced anemia prevalence in 4-year-old preschoolers (Francisco Plácido Nogueira Arcanjo, 2012).

Fortification of Encapsulated Iron In Probiotic Yoghurt: As yoghurt is lacking in iron, Jailalita *et al*. of Madras Veterinary College (2012) researched to fortify ferrous sulphate in probiotic yoghurt as encapsulated form. Study revealed that iron fortification does not affect the viability of probiotic bacteria (Jailalitha, 2012).

Fortification of Soy Sauce using various iron sources

Watanapaisantrakul R *et al*.(2006) in Thailand ,conducted a study of fortification of soy sauce using various iron sources and saw its sensory acceptability and shelf stability. Seven iron sources were tested for their feasibility for fortification of four types of soy sauce. Five iron sources--ferrous sulfate, NaFeEDTA, ferric ammonium citrate, ferrous lactate, and ferrous gluconate--did not significantly affect the sensory qualities of the product over a period of 3 months .Ferrous fumarate and ferrous bisglycinate caused unacceptable precipitation. It was concluded that both naturally fermented and chemically hydrolyzed soy sauces could be fortified with all five iron sources. Ferrous sulfate is the most appropriate source because of its low cost and acceptable sensory characteristics & Soy sauce is a promising vehicle for iron fortification (Watanapaisantrakul, 2006).

Iron fortification of sugar

Kimberly M. Stangl (May 2008) studied to compare the impact of selected iron fortificants (NaFe-EDTA, iron bis-glycinate, elemental iron powder, or ferrous sulfate) on the color of granulated sugar and two products sweetened with the sugar. Elemental iron was the best for granulated sugar, but NaFe-EDTA was most suitable for the candy, and for the tea, since the elemental iron is insoluble in water (Kimberly, 2008).

Fortification of common salt with iron

According to the article published by Sayers MH *et al*. (2008) crude common salt could be fortified with 0.1% iron as $FePO_4$, and 1.25% ascorbic acid and stored under all but the most extreme tropical conditions, provided that 2.5% starch was added to prevent the development of discoloration, and that such fortification would significantly improve the iron nutrition in countries where the staple food is rice or maize (Sayers, 2008). Diosady L.L (2009) stated that the incidence of anemia in rural and urban communities of India was reduced by the introduction of salt fortified with iron (Diosady, 2009)

Iron Fortification of Potable Drinking Water

Dutra de Oliveira *et al*. (2002) said that the iron fortification of drinking water is an effective, feasible alternative and practical way to distribute iron to low-income families, is technically inexpensive and has the promising potential for the control and prevention of anemia in Brazil and in other countries (Dutra-de-Oliveira, 2002). To study the effect of iron fortification of potable drinking water, Beinner *et al* in 2005, took 160 preschool children from eight municipal daycare facilities in Brazil who are benefited from daily consumption of iron (12 g element iron/L) plus ascorbic acid (90 mg/L) prepared in 20-L plastic water jugs. The prevalence of iron deficiency determined by hemoglobin levels decreased from 43.2% to 21% at eight months post intervention (Beinner, 2005).

Wheat and corn flour iron fortification

In Brazil, since 2001 the Ministry of Health made mandatory the addition of iron to milled wheat and corn flour. According to Beinner & Lamounier,2003, iron-fortified wheat flour is not always available, or it is consumed in small quantities to be affective by poor children 6 to 60 months of age (Beinner, 2003). To increase the accessibility of milled cereal grains with iron and folic acid consumed by the Brazilian population and to reduce the prevalence of iron-deficiency and neural tube defects in Brazil what and corn flour fortification was initiated in Brazil (National Agency of Sanitary Surveillance, 2006).

Iron fortification of Biscuit and Bread rolls

Vellozo *et al*. (2003) said that biscuits and sweet rolls, this two vehicles complement each other, resulting in a significant reduction of the population below the iron RDAs when fortified with iron (Vellozo, 2003).

Iron absorbtion from iron fortified Corn Flakes

Marı´a Nieves Garcı´ a- Casal *et al* (2003) studied to determine relative iron absorption from reduced iron-fortified Corn Flakes and the role of vitamins A and C improving absorption. There was a significant 3.6-times increase in iron absorption when both vitamins were administered together (Marı´a Nieves Garcı, 2003).

Extruded Rice fortified with Ferric Pyrophosphate: In a double blind randomized school based control trial in Bangalore,India among 6-13 years old children(n=184) by Moretti D *et al* (2006) ,it was found that extruded rice fortified with ferric pyrophosphate reduces iron deficiency in Indian school children (Marı´a Nieves Garcı, 2003).

Iron Fortification of Infant Foods: Sharieff *et al*. in 2006 stated that Bolivia was the first country that has documented the use of home fortification with intervention at the level of public health (Sharieff, 2006).

Herrera in **2007** reported that Milk fortified with iron is distributed, also at subsidized prices, to children under one year since 2005, and the program has covered 98% in Brazil (Herrera, 2007).

According to Sprinkles Global Health Initiatives, 2009 for children under one year, the most appropriate strategy seems to be the fortification of child foods at home. Zlotkin and colleagues at the Hospital for Sick Children, University of Toronto (Canada) developed a less costly alternative of the provision of micronutrients which an be added to infant foods. It was named "home fortification" and used sprinkles, the multiple-micronutrient sachet. The biological efficacy, bioavailability, safety and acceptability of Sprinkles were tested in various scenarios, including countries such as Bangladesh, Benin, Bolivia, China, Canada,Ghana, Guyana, Haiti, India, Indonesia, Kyrgyzstan, Mexico, Mongolia, Pakistan, Vietnam (http://www. sghi.org/index.html)

Iron fortification of Rice

Nogueira Arcanjo *et al* (2012) evaluated that use of iron fortified rice reduces anemia in infants in Brazil.Iron-fortified rice was effective in increasing hemoglobin levels and reducing anemia in infants (Nogueira Arcanjo, 2012).

A study was conducted by Beinner *et al*, in 2009 with families in the metropolitan area of Belo Horizonte. A group of 84 children received iron-fortified rice (23 mg Fe / day) and another group received ferrous sulfate (25 g Fe / L). After five months of intervention, there was a reduction in the prevalence of anemia in both groups, with an initial prevalence of 100% in both groups, decreasing to 61.9% for the group receiving the fortified rice and 85.6% for the group receiving ferrous sulfate, with a significant difference between groups (Beinner, 2009). Regarding rice, more studies are needed to evaluate the timing and dose required fortification of that vehicle, to achieve preventive effects and / or significant curative as well as assess the effect of simultaneous use with other supplements containing iron.

Sensory acceptability of iron fortified millet products

In the investigation done by Tripathi B *et al* in 2011, two products prepared from finger millet and sorghum flours fortified with iron and ethylene diamine tetraacetic acid(EDTA) and stored for up to 60 days were evaluated for sensory quality attributes and their texture was measured using a texture analyzer. It was found that there was no significant effect of the fortificant on the texture and aroma of the products prepared from the fortified flours up to a period of 60 days. The overall quality of the roti prepared was acceptable to the sensory panelists. Finger millet and sorghum flours seem to be suitable as vehicles for fortification with iron (Tripathi, 2011).

Iron fortification of staple food

Omar Dary in 2008 said that Fortification of staple foods is an adequate strategy to provide additional iron to populations. They also discussed regarding bioavailability, technologic compatibility, and cost effectiveness, advantages of fortifying staple foods with iron and the indispensable need to combine this strategy with other interventions (Omar Dary, 2008).

Fortification of Maize flour with iron

In 2010 a study rather trials conducted by Akzo Nobel (Wageningen University) in collaboration with Unilever Food and Health Research Institute, The Netherlands and Kenya Medical Research Institute *to assess whether NaFeEDTA and electrolytic iron improve iron status of young school children, when added as iron fortificants in whole maize flour.* Isotope studies have shown that even in the presence of phytates, iron from NaFeEDTA is relatively more bioavailable than that from other fortificant sources. Electrolytic iron, on the other hand is widely used and was legislated as the iron fortificant of choice in South Africa. Its efficacy in a high-phytate vehicle has also not been assessed (Akzo Nobel, 2010). Sant-Rayn Pasricha in 2011 fortify maize flour with iron for preventing anaemia and iron deficiency in general population (Sant-Rayn Pasricha, 2011).

In vitro iron availability from iron fortified whole grain wheat flour

In the study, done by Kloots W *et al* in 2004 , fortified whole-grain wheat flour with different sources of iron was evaluated in vitro by measuring the amount of dialyzable iron after simulated gastrointestinal digestion of flour baked into chapatis and subsequent intestinal absorption of the released iron. The dialyzability of iron from iron-fortified wheat flour was extremely low. Relative to iron from ferrous sulfate, iron from SunActive Fe and NaFeEDTA appeared to be 2 and 7 times more available in the in vitro assay, respectively.On the basis of these results it appears that fortification with NaFeEDTA may result in whole-grain wheat flour that effectively improves the iron status (Kloots, 2004).

Iron fortification of Wheat flour

To assess the relationship between average monthly per capita household consumption of iron-fortified wheat flour and iron deficiency among women of childbearing age in Oman a study was done by Grimm *et al* (2012). Results showed Consumption of iron-fortified wheat flour was associated with a lower prevalence of iron deficiency among women (Grimm, 2012). In september 2012 Muthayya S *et al* studied on Indian School –aged children. They found that Iron fortification of whole wheat flour reduces iron deficiency and iron deficiency anemia and increases their body iron stores. NaFeEDTA is the only iron (Fe) compound suitable for fortifying high extraction flours.. It may be recommended for wider use in national school feeding programs (Muthayya, 2012). Fortification of wheat flour and maize meal with different iron compounds (sodium iron ethylene diamine tetra acetate [NaFeEDTA], ferrous fumarate, or ferrous sulfate) were conducted by Randall P *et al* in 2012. Bread, chapatti, ugali (thick porridge), and uji (thin porridge) were prepared locally and assessed on whether the products were acceptable under industry-approved criteria. The study concluded that the levels of iron compounds used, in accordance with the WHO guidelines, do not lead to changes in the baking and cooking properties of the wheat flour and maize meal (Randall, 2012).

Whole cowpea meal fortified with NaFeEDTA

To test the efficacy of NaFeEDTA-fortified cowpea meal in improving iron status of school children in a malaria endemic area Abizari *et al* (2012) studied on 241 Ghanaian school children (5-12 years) in a malaria endemic area .Fortification resulted in a 30 % and 47% reduction in the prevalence of iron deficiency (ID) and iron deficiency anemia (IDA). The results indicate that fortification of cowpea flour with NaFeEDTA overcomes the combined inhibitory effect of phytic acid and polyphenol and, when used for targeted school-based fortification of cowpea flour, is effective in reducing the prevalence of ID and IDA among school children in malaria endemic rural northern Ghana (Abizari, 2012).

Iron Fortificants used in various food vehicles (Lindsay Allen, 2006)

When *selecting a suitable iron compound* as a food fortificant, the *overall objective is to find the one that has the greatest absorbability*, i.e. the highest relative bioavailability (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*. *Cost* is usually another important consideration. A wide variety of iron compounds are currently used as food fortificants. These can be broadly divided into three categories:

- water soluble;
- Poorly water soluble but soluble in dilute acid;
- Water insoluble and poorly soluble in dilute acid.

Water soluble compounds

Being highly soluble in gastric juices, the water-soluble iron compounds have the *highest relative bioavailabilities* of all the iron fortificants. The water-soluble forms of iron are *especially suited to fortifying cereal flours* that have a relatively fast turnover, i.e. one month in warm, humid climates and up to 3 months in dry, cold climates. Water-soluble iron compounds are *also useful for dry foods*, such as pasta and milk powder, as well as dried milk-based infant formulas.

Ferrous sulfate is by far the most frequently used water-soluble iron fortificant, principally because it is the cheapest. It has been widely used to fortify flour. However, depending on its physical characteristics, the climate and the fat content of the flour to which it is added, ferrous sulfate can cause rancidity, and therefore its suitability as a fortificant needs to be evaluated in trials before use. Examples:- Ferrous sulfate. $7H_20$, Ferrous sulfate dried, Ferrous gluconate, Ferrous lactate, Ferrous bisglycinate, Ferric ammonium citrate, Sodium iron EDTA (NaFeEDTA)

Iron compounds that are poorly soluble in water but soluble in dilute acid

Compounds that fall into the second category of iron fortificants are also reasonably well absorbed from food, as they are soluble in the gastric acids produced in the stomach of normal healthy adults and adolescents. *Ferrous fumarate* and *ferric saccharate* are the most commonly used iron compounds in this group, and in adults are as bioavailable as ferrous sulfate. Ferrous fumarate is used to fortify maize flour in Venezuela and wheat flour in Central America, where it has also been proposed as a potential fortificant for maize masa. Ferrous fumarate can be used in an encapsulated form to limit sensory changes.

Iron compounds that are insoluble in water and poorly soluble in dilute acid: Relative to ferrous sulfate, the absorption of iron from water-insoluble compounds ranges from approximately 20% up to 75%. Despite their reduced absorbability, water-insoluble iron compounds have been widely used by the food industry as fortificants because *they have far less effect on the sensory properties of foods* (at the levels currently used) and because they are *cheaper than the more soluble compounds*. Within this category of iron fortificants, the ferric phosphate compounds – ferric orthophosphate and ferric pyrophosphate – are used to fortify rice, and some infant cereals and chocolate-containing foods. They have a modest iron bioavailability. Elemental iron powders are used in a number of countries to fortify cereals, but the bioavailabilities of the different forms of elemental iron that are currently available are not well established.

Novel iron fortificants: In recent years, considerable effort has been devoted to the development and testing of alternative iron fortificants, in particular, fortificants that provide better protection against iron absorption inhibitors than those currently available. Among those at an experimental stage are sodium iron EDTA (NaFeEDTA), ferrous bisglycinate and various encapsulated and micronized iron compounds. In recent years, NaFeEDTA has been selected as the iron compound to fortify government-led soy sauce fortification and wheat flour fortification programs in China, and fish sauce fortification in Vietnam.

Sodium iron EDTA :In high-phytate foods, the absorption of iron from NaFeEDTA is 2–3 times greater than that from either ferrous sulfate or ferrous fumarate.

Advantages: NaFeEDTA offers a number of other advantages: it *does not promote lipid oxidation* in stored cereals, or the formation of precipitates in foods that are high in free peptides, such as soy sauce and fish sauce.

Disadvantages: On the down side, it is expensive, and because it is slowly soluble in water, it may cause colour changes in some foods.

Ferrous bisglycinate: Ferrous bisglycinate is an iron–amino acid chelate in which *the iron is protected from the action of absorption inhibitors by being bound to the amino acid, glycine*. Absorption from this form of iron has been reported to be 2–3 times better than that from ferrous sulfate in a high-phytate cereal and in whole maize.

Advantages: Ferrous bisglycinate seems to be particularly well suited to the fortification of liquid whole milk and other dairy products where use of ferrous sulfate leads to rancid off-flavours.

Disadvantages: Ferrous bisglycinate can also cause rancidity by oxidizing fats in food unless anti oxidant is added. Furthermore, the bisglycinate is much more expensive than many other iron compounds.

Encapsulated ferrous sulfate and ferrous fumarate: Several iron compounds are available commercially in encapsulated form, namely ferrous sulfate and ferrous fumarate, and are currently *used* in dry infant formulas and in infant cereals, predominantly in industrialized countries. The main purpose of encapsulation is to separate the iron from the other food components, thereby mitigating sensory changes.

Micronized ferric pyrophosphate: Micronizing insoluble iron salts to an extremely small submicron particle size be achieved, only by a chemical process. It is available in both liquid and dried forms. In order to make it dispersible in liquids, the particles of ferric pyrophosphate are coated with emulsifiers. Relative to ordinary ferric pyrophosphate (mean particle size of around 8 microns), iron absorption by adult humans is improved by 2–4 four times in milk products. Its principal advantage is that, being insoluble in water, it is unlikely to cause many sensory problems, although this remains to be tested adequately. Currently it is added to liquid milk and yoghurt products in Japan.

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