

Review on analysing food vehicles for iron fortification and selecting a best for Sri Lankan target people

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Abstract

Micronutrients require in minute quantities but play a vital role in normal human growth, development and physiological functioning. The deficiencies of them, essentially vitamins and minerals, mainly cause several illnesses, especially in children and women worldwide. Of those, iron is a mineral that is necessary for producing red blood cells in order to cure the disease anaemia. Iron deficiency is considered to be the commonest worldwide nutritional deficiency and affects approximately 20 % of the world population. One of the strategies that could be initiated in order to control iron deficiency anaemia is fortification of food with iron, so as to improve the nutritional quality of the food supply with minimal risk to health. This paper reviews the iron fortified food products available, bioavailability of iron type on them, cons and pros by iron fortification on each available food products, suitability analysis of fortified food products to all the people and finally suggesting a best food vehicle for iron fortification in Sri Lanka. As a result, although there are several food vehicles suitable for other countries, it can be concluded that rice is the staple food and highly consuming by all the target and non-target people in Sri Lanka. So, it has been decided as the best food vehicle for iron fortification. Even though rice was considered as best food fortificant vehicle, it is recommended to analyse the uniformity of iron distribution in fortified rice sample after cooking in order to assure uniform iron intake for the target people while reducing possible bad effects due to high doses.

Keywords: anaemia, fortification, iron, rice, Sri Lanka

Introduction

About one third of the Sri Lankans suffer from iron deficiency and this is the most widespread micronutrient deficiency in Sri Lankan population. Vitamins (A, B, C, D, E & K), Minerals (Iron, Zinc, Sodium, Potassium, Calcium, Phosphorus & Fluoride) and trace elements (Iodine, Copper, Selenium, Manganese, Chromium & Molybdenum) are referred to as micronutrients. They are required in minute quantities, in contrast to macronutrients. They are playing an important role in normal human growth & development, physiological functioning and maintenance of health (Shergill, 2017) [15]. The unable condition by the human body to synthesize micronutrients, lead to dietary intake of them. However, a diet inadequate in micronutrients, result in various negative health consequences (Haas and Brownlie, 2001) [8]. The amount of micronutrients required cannot be determine as it depends on several factors like age, sex, lifestyle, hormone status and the half-life & bioavailability of the micronutrient. Micronutrient deficiency are referred to as "Hidden hunger" because they are progressive, and cannot be identified clinically until they are in their late stages (Hans & Jana, 2018) [9].

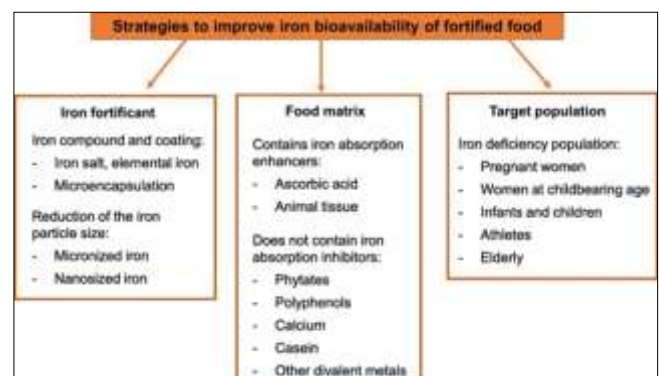
There are several strategies to reduce iron deficiency anaemia

- Diversified and modified foods that aims to increase the content and bioavailability of iron in the food (FAO / CAB international 2011).
- Iron supplementation through tablets or syrups
- Blood transfusion, only for very severe anaemia
- Bio fortification through conventional plant breeding or genetic engineering that increases the iron content or its

bioavailability in edible plants and vegetables

- Iron fortification with staple foods (typically rice, maize, soy and wheat flour) (WHO/FAO, 2006) [2,3].

Some of these strategies are population based while others are targeted at specific age groups or consumer groups. This paper describes the strategy-iron fortification with staple foods to reduce the iron deficiency anaemia. In this method, there are some strategies to improve iron bioavailability of fortified food are shown in figure 1.



Source: (Rojo and Vaquero, 2019)

Fig 1: Strategies to improve iron bioavailability of fortified food

Iron fortification of foods is associated with improved iron status, and reduced anaemia among populations (Gera, 2012) [7]. The benefit from an iron fortification programme and its sustainability, depends not only on factors such as regular intake of the chosen vehicle across the entire

population, the quantity of added iron and its bioavailability, but also on the organization of the industrial sector in a given country. Adolescents constitute a risk group for iron deficiency with important consequences for health, due to the period of rapid growth, body mass increase, expansion of blood volume, an onset of menstrual loss in girls associated with a poor diet (Camaschella, 2015)^[2].

Horton & Ross, 2003^[10] stated that the economic costs of iron deficiency anaemia resulting from annual physical productivity losses have been calculated to be around 0.57 % of Gross Domestic Product (GDP) in low- and middle-income countries. Therefore, iron deficiency anaemia not only reduces the work capacity of individuals but could also bring serious economic consequences and obstacles to natural development.

Because of all this, reduction of the global burden of iron deficiency is generally considered within the scope of public health nutrition (Pasricha and Drakesmith, 2016)^[12]. In fact, in 2012, the world health assembly resolution 65.6 endorsed a “comprehensive implementation plan on maternal, infant and young child nutrition”, which specified six global nutrition targets for 2025 (WHO, 2012)^[22], the second target being to “achieve a 50% reduction of anaemia in women of reproductive age” (WHO, 2014)^[23]. In this regard, public health strategies to prevent and control anaemia include several options that are currently available for providing iron, but among them iron food fortification seems to present the best risk benefit balance (Prentice *et al.*, 2017)^[13].

In contrast, iron excess leads to several diseases (Toxqui *et al.*, 2010, Vaquero, Garcia- Quismondo, Canizo, & Sanchez- Muniz, 2017)^[16, 20]. Therefore, subjects at risk of iron excess owing to genetic or acquired diseases should be protected in situations where mass fortification policies are applied. The choice of the food vehicle should be based on consumption data. More specifically, there must also be a balance between intake of vehicle and amount of iron added to achieve estimated effective daily iron absorption of about 1 to 2 mg per day (WHO, 2009)^[21].

The correct combination of iron form and food vehicle is crucial, as well the dietary context of consumption. Combinations of iron with an enhancer of its bioavailability and avoidance of interaction with iron inhibitors are recommended. Globally, almost half of the children aged between 6 and 59 months had anaemia, and one in three women of reproductive age were anaemic (WHO, 2015)^[24]. This data show that iron deficiency affect more people than any other condition. (Fig 2)

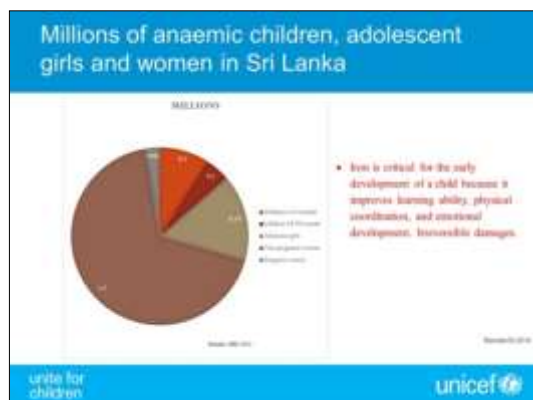


Fig 2: Graph showing millions of anaemic children, adolescent girls and women in Sri Lanka

Iron bioavailability

The term bioavailability of iron emerged from the proportion of iron absorbed and used through normal metabolic pathways or stored. The more soluble the iron compound, the greater its potential absorption and thus its bioavailability (Vaquero, 1992)^[16]. It is expressed as percentage of intake and is known to be influenced by dietary factors (Aggett, 2010)^[1].

The amount of iron absorbed, form of iron, enhancers and inhibitors are the prerequisite for having bioavailable iron. Animal feeds such as good sources of highly available iron party by means of their haem iron content, which is approximately 40 % of total iron (Monsen *et al.*, 1978)^[11].

Ferrous iron has generally been assumed to be better absorbed than ferric iron, but in fact both ions can be efficiently absorbed, provided that they reach the mucosa in a soluble form. The limiting point is solubility, as ferric salts can precipitate when pH rises from the stomach to the duodenal area. This precipitation can be prevented by complexation of iron with compounds that form absorbable chelates that remain soluble at increasing pH (Van Dokkum, 2003)^[18]. In addition, dietary compounds that reduce iron from ferric to ferrous generally increase bioavailability. Ascorbic acid & animal tissue are the main enhancers, whereas phytic acid and polyphenols are the main inhibitors. Compounds used in food fortification provide non heme iron, so it is important to select fortification compounds and food vehicles that will not diminish iron bioavailability (Van & Letsky, 2000)^[17].

Mass large scale fortification of staple foods or condiments is a preventive strategy aimed at reducing the risk of developing iron deficiency through increased dietary iron. Iron fortification aims to reduce pre-existing iron deficiency and is designed and implemented to reach the whole population. Mass targeted or market driven food fortification with iron has been used with various vehicles: rice, wheat, maize, yoghurt and pasteurized milk, sugar & beverages, fish sauce & soy sauce etc (WHO/FAO, 2006). Further, this paper reviews each food fortification vehicle and its suitability to the common people in Sri Lanka.

1. Rice as food fortificant vehicle

Micronutrient deficiencies of public health significance are widespread in most countries consuming high levels of rice; thus, rice fortification has the potential to help aid vulnerable populations that are currently not reached by wheat or maize flour fortification programs. Rice is the basic staple food in Sri Lanka as such can be a valuable vehicle to alleviate the nutrient deficiencies (Liyanage *et al.*, 2011).

Bioavailability of iron is fairly low in vegetable, cereal food items, almost at the level of 10% (Anthonyswamy *et al.*, 2016). Several methods have been applied to improve iron content and bioavailability in rice seed. Apart from breeding and genetic engineering, biochemical and physical approaches have frequently been used as prospective methods to regulate iron content and bioavailability in rice grains (Fanuhuna *et al.*, 2005). Fortification of rice is the practice of deliberately increasing the content of an essential micronutrient, vitamins and minerals in rice, to improve the nutritional quality of the food supply and provide a public health benefit with minimal risk to health.

Globally, anaemia affects 24.8% of the population of which 50% is due to iron deficiency (Bonoist *et al.*, 2008).

Fortification of rice with iron is recommended as a public health strategy in setting where rice is a staple food by WHO and FAO. It is identified for decreasing the incidence of nutrient deficiencies at the global level.

Health survey in 2007 found an estimated overall prevalence of iron deficiency anaemia of 34% in Sri Lanka, with 20.7% mild anaemia and 13.3% moderate to severe anaemia. The island-wide Iron Deficiency Survey was carried out between 2009-2010 in an adolescent population of 7526. This survey reports that, iron deficiency occurred in 34.9% of the population, but iron deficiency anaemia occurred only in 3.9% of them (Premawardhena *et al.*, 2018). Low iron status and anaemia remain common problems in Sri Lankan secondary school students especially females, young students, and the socioeconomically disadvantaged people. Sri Lankan Cabinet has approved iron fortification of staple foods like rice and wheat flour to mitigate this health issue in 2009. As a field trial, school children in Anuradhapura District are fed with iron-fortified rice as their mid-day meal (Ruwani *et al.*, 2019). Iron is considered one of the most limiting micronutrients, especially in diets mainly with polished rice. Unpolished rice contains about 2.6 mg iron/100 g. However, in polished rice, the iron level can be as low as 0.4–0.6 mg/100 g.

Considering the low bioavailability of iron in unpolished rice due to the amount of phytate, (Hurrell *et al.*, 2010) the physiological effect of the reduction of intrinsic iron from milling is expected to be low. Iron fortification and polishing of rice improves the phytate: iron ratio. Milled rice is low in micronutrients because its nutrient rich outside layer is removed during typical rice milling and polishing operations. This makes the grain taste better and more visually appealing, but less nutritious.

The common methods of fortification include extrusion, coating and dusting. Nutrient loss is high in coating and dusting while washing before cooking. Extrusion is the most promising technology for rice fortification because in the extrusion technology that the micronutrients are infused inside the kernel. Iron-fortified rice is the enrichment of ferric pyrophosphate to rice at a rate of 8mg/100g (serving) which will convert into ferrous while cooking. Therefore, the more absorbable ferrous form reaches the target population easily in Sri Lanka.

2. Wheat

Wheat is the third largest cereal production in the world, after maize and rice and the second most consumed in the diet after rice. It is estimated that about 65 % of the wheat crop is used for food while 17 % for animal feed and 12 % in industrial applications, including biofuels (FAO, 2013).

Wheat as iron fortificant also leads a major role for Sri Lankan target people due to their consumption pattern. It is the second most suitable vehicle for Sri Lankans.

3. Maize

In public health, fortifying staple foods is considered one way of reducing micronutrient deficiencies without changing usual and culturally acceptable diets.

Maize (corn) is one of the world's most important cereal grains. In sub-Saharan Africa, some parts of Southeast Asia and Latin America, where iron deficiency is endemic, maize is a dietary staple for more than 200 million people. Fortification of maize flour with iron is mandatory in Brazil,

Costa Rica, El Salvador, Kenya, Mexico, Nigeria, Rwanda, South Africa, Tanzania, Uganda, the USA and Venezuela.

Maize contains only modest amounts of zinc and negligible amounts of iron, absorption of which is further diminished by the presence of phytates: the bioavailability of iron from corn is thus estimated to be less than 5% (Beiseigel 2007). Phytases, genetically modified low-phytate maize variants, and some pre-processing methods such as addition of ascorbic acid, may improve iron availability from maize (Beiseigel 2007; Hurrell 2002; Troesch 2011).

Voluntary fortification of maize with iron has been introduced in Ghana, Malawi and Mauritania (Peña-Rosas 2014a). Fortification programmes require support by legislative frameworks that include regulations and standards to ensure the appropriate micronutrient contents are added to the foods and appropriately labelled (Makhumula 2014). So, it is considering as the third suitable vehicle for Sri Lankans while most suitable in other countries.

4. Yoghurt & Pasteurized Milk

Iron fortification of milk and dairy product is considered as a potential approach to prevent the iron deficiency disorder (Gaucheron, 2001) ^[6]. Since dairy foods are an important part of the daily diet in most parts of the world. Fortification with iron is technically more difficult than fortification with other nutrients because iron is a pro-oxidant and therefore promotes lipid oxidation (EI-Kholy *et al.*, 2011) ^[3].

Therefore, the ideal iron compound for food fortification should be one that supplies high bioavailability of iron and does not affect both nutritional value and sensory properties of the food during processing. As these food vehicles are not consuming in daily basis, it is not suitable for targeted people due to the inefficiencies.

5. Sugar & Beverages

In vitro studies demonstrated that ferrous sulphate added to sugar in proportion of 1mg to 1g, respectively, is maintained in the ferrous form for a period of at least 1 year and does not induce adverse changes in the vehicle. Sugar, by itself carries practically no inhibitors for the absorption of iron. Iron absorption from fortified sugar is the same as that of native iron. The absorption from fortified sugar is increased more than 50% over that observed from native when it is administered as a drink during the ingestion of a meal.

A further increase in absorption was found when fortified sugar was administered with beverages. The mean absorption ratio of fortified sugar given with orange juice and coca-cola to a reference dose of iron ascorbate was between 0.45 and 0.66, which is more than 3 times the absorption of this iron fortification. The mean absorption ratio from coffee was 0.30, and from coffee with milk, 0.15. These data indicate that the fortification of sugar with iron could be a better procedure for the prevention of iron deficiency than the iron fortification of bread and wheat products, from which iron is poorly absorbed.

It could be used in developing countries where beverages are highly consumed by the low socioeconomic class. The absorption comparison between ferric and ferrous salts added to sugar demonstrated that Fe (III)-EDTA reacts slowly with the tannin contained in tea; the colour of the tea changes slightly in the first two hour after the addition of the fortified sugar.

The constrain behind this sugar fortified with iron is the

reluctant of reaching target people who are having diabetes and also those who are not willing for drinks and sugar.

6. Fish sauce & Soy sauce

In Vietnam, prime minister had ratified the national nutrition strategy 2001- 2010, in which elimination of micronutrients deficiencies is one of the objectives and fortification of food is an important strategy.

With the support of global alliance for improved nutrition, the national institute of nutrition has been implementing the iron fortified fish sauce project in Vietnam. This is an advantaged solution and suitable for all people especially the poor who can buy iron fortified fish sauce at an affordable price as they are facing high risk of iron deficiency anaemia.

In 2002, the average anaemia prevalence in china was 20.1% and the prevalence in women of child bearing age and of children in some poor regions reached more than 50 %. Soy sauce, a widely-used condiment, was developed as a carrier for food fortification in china to control and prevent iron deficiency and iron deficiency anaemia.

As mentioned, fish and soy sauce are suitable to countries where people consuming these willingly like china and Vietnam, not in Sri Lanka.

Conclusion

Fortification has an opportunity to be a more cost effective and efficacious treatment for iron deficiency and iron deficiency anaemia than other possibilities like supplementation, transfusion etc. in many developing countries.

Each of the possible and available fortificants reviewed in this chapter were efficacious in improving iron status in a controlled environment. However, in many cases this does not provide assurance that adopting these fortificants will be effective in every community.

As with fortification, many other development strategies, the approach will vary across, and even within countries, which makes developing guidelines for the treatment of iron deficiency difficult. What works in one country will likely not work in the exact same way in a neighbouring country, and the same can be said from one village to the next. However, some of the fortificants, that were reviewed in this chapter demonstrated greater success in different regions of the world than other. The use of rice as iron fortificant is the best acceptable strategy among all other fortificants to reduce iron deficiency in the people living in Sri Lanka as they adapt consumable, preferable and staple food is rice.

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