Iron Fortification of Rice for Combating Iron Deficiency Anaemia

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ABSTRACT
Iron deficiency is thought to be the most common cause of anaemia globally. Nearly 58% pregnant women, 50% non-pregnant non-lactating women, 56% adolescent girls, 30% adolescent boys and around 80% children under 3 years of age are anaemic in India. Interventions to prevent and correct iron deficiency and iron deficiency anaemia, include measures to increase iron intake through food-based approaches, iron supplementation and improved health services and sanitation. Fortification of food with iron is considered more cost-effective and economically more attractive than iron supplementation. Since rice is the staple food of India, Sampada, a popular rice variety, was fortified through parboiling using Na2FeEDTA as source of iron. The present process of fortification is simple and cost effective and provided iron in the range of 35-40 ppm in the fortified rice. Sensory evaluation and consumer acceptability studies showed that the iron fortified rice product was well accepted by the respondents. Feeding trials of the fortified rice showed that haemoglobin level in severe anaemic subjects significantly (p<0.01) increased from 6.77 ± 0.28g /dl on 0th day to 10.36 ± 1.35g /dl on 60th day while in moderate group it significantly (p<0.01) increased from 9.25 ± 0.73g /dl on 0th day to 10.83 ± 1.40g /dl on 60th day. The haemoglobin level also increased from 0th day to 60th day in subjects with mild anaemia from 11.75 ± 0.21g /dl at baseline (0th day) to 11.83 ± 0.46g /dl on 60th day, but the increase was not statistically significant. The study also showed that there was no significant change in the haemoglobin level of the anaemic subjects of control group. Hence it can be concluded that the rice fortified with NaFeEDTA can be an effective solution to prevent the enormous prevalence of anaemia.

KEY WORDS: Fortification, Iron Deficiency, anaemia, Haemoglobin, Sensory evaluation, Consumer acceptability.

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INTRODUCTION
Anaemia is a condition in which the number and size of red blood cells, or the haemoglobin concentration, falls below an established cut-off value, consequently impairing the capacity of the blood to transport oxygen around the body. The function of the RBCs is to deliver oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs by using haemoglobin (Hb) that contains iron molecules. Anaemia has three main causes: blood loss, high rate of RBCs destruction and decreased production of RBCs. A diet that lacks iron, folic acid or Vitamin B12 or the condition that make it hard for our body to absorb nutrients can also prevent our body from making enough RBCs. Iron deficiency is thought to be the most common cause of anaemia globally. Iron deficiency can be caused by several factors such as decreased iron intake, increased iron loss from the body, and increased iron requirement.

Prevalence of Anaemia
Based on available data (Cheema et al., 2016; WHO 2008), anaemia affects 1.62 billion people globally with about 293 million children of preschool age, 56 million pregnant women, and 468 million non-pregnant women. Children and women of reproductive age are most at risk, with global anaemia prevalence estimates of 47 per cent in children younger than 5 years, 42 per cent in pregnant women, and 30 per cent in non-pregnant women aged 15–49 years. Anaemia is estimated to contribute to more than 115,000 maternal deaths and 591,000 prenatal deaths globally per year. The National Family Health Survey (NFHS-3, 2006) reveals that anaemia is widely prevalent among all age groups in India. This is particularly high among the most vulnerable with nearly 58% among pregnant women, 50% among non-pregnant non-lactating women, 56% among adolescent girls (15–19
Iron is the staple food of India and its Per capita consumption (in 2016) is in the range of 17–0.2 mg Fe/kg body weight per day (WHO, 1999). Fortification of food with Iron is considered more cost-effective and economically more attractive than iron supplementation and dietary interventions (Hurrell, 2002). The WHO recommends iron compounds for cereal fortification purposes and the choice of the compound should be made considering local regulations, sensory properties and its bioavailability (WHO, 1999). Ferrous sulfate is the principal iron compound used in cereal fortification studies. However, it can only be added satisfactorily to a small number of food vehicles. The disadvantage of ferrous sulfate is that it readily reacts with other substances that are naturally present in the food matrix and can modify the physical properties of the final product made with the fortified product. Presence of absorption inhibitors, such as phytic acid or phenolic compounds reduces iron absorption.

Sodium iron ethylenediaminetetraacetec acid (NaFeEDTA) is another FAO approved food additive (WHO, 1999) which has the advantage over other fortification compounds. It prevents iron binding to inhibitors of iron absorption and to phytic acid in particular. Thus iron absorption from NaFeEDTA, which is added to foods containing a considerable amount of phytic acid, is two- to threefold higher than from ferrous sulfate. NaFeEDTA can be used in areas with a high prevalence of iron deficiency, at a maximum intake of 0.2 mg Fe/kg body weight per day (WHO, 1999).

Rice is the staple food of India and its Per capita consumption (in 2016-17) is 74.2 kg while the world average is 61.2 kg (Anonymous, 2017). Unfortunately, polished rice which is mainly consumed contains only 4-5 parts-per-million (ppm) of iron. But, the recommended daily allowance of iron as per Indian Council of Medical Research (ICMR) for adult is in the range of 17-35 milligrams (NIN 2009). Therefore, iron fortification of rice appears to be the best long-term nutrition intervention strategy for combating iron deficiency anaemia.

**MATERIALS AND METHODS**

**Iron Fortification of Rice**

Six rice varieties were grown in field plots with the same soil type. The experiment was laid out in completely randomized block design with three replicates per cultivar. Rice grains were harvested at maturity, with a great care to minimise the chance of Fe contamination in the field. Approximately 150 g of paddy rice were sub-sampled and rinsed thoroughly in three changes of distilled deionised water (DDI) before applying treatments. For Fe fortification treatments, rinsed paddy rice were soaked with 150 ml of Fe solutions. NaFeEDTA was used as source of Iron. For the control unfortified parboiled rice, rinsed paddy rice was soaked with 150 ml of distilled triple deionised water (TDI) for 24 h at room temperature.
Soaked grains were steamed for 10 min. The grains were cooled and sun-dried to approximately 12% moisture content.

**Husking and milling**
The dried grains (approximately 12% moisture content) of parboiled rice were separated into brown rice and husk with a testing husker (Satake, Japan). For each sample, 40 g of the brown rice were milled for 120 s to yield white rice by using a laboratory milling machine (Satake, Japan). Metal parts of the husker and polishing machine were cleaned by sand-blasting and coated with Teflon to minimise Fe contamination in rice samples (Prom-u-thai, et al., 2007). Weights of milled grains were recorded for calculating the percentage of head rice yield and degree of milling (Prom-u-thai et al., 2007). Iron content was estimated using XRF (Azam et al., 2017).

**Sensory Evaluation and Consumers Acceptability**
In order to know the consumer acceptability of the fortified product, sensory properties were studied using six rice products (plain rice, carrot rice, vegetable biryani, pudina rice, keher and pulihora) prepared with both iron fortified and normal rice and were subjected to sensory evaluation according to the procedure mentioned elsewhere (Sarkar et al., 2015, Rizwana et al., 2017). A total of 100 subjects, including 18 males and 82 females were randomly selected for the consumer acceptability study from the age group of 18-60 years and serve them vegetable biryani made from normal and iron fortified rice.

**Effect of Iron-fortified Rice on Haemoglobin level**
A study was planned to assess the effect of iron-fortified rice on the blood haemoglobin levels of anaemic girls. Details have been mentioned elsewhere (Sarkar et al., 2016). In short, vegetable Biryani was cooked with 100 g of raw iron fortified / normal rice for each subject and served thrice weekly to the selected subjects for a period of 2 months (60 days) to the experimental group and control group, respectively. The blood haemoglobin levels were checked on 0, 30 and 60 days according to the procedure mentioned earlier (Sarkar et al., 2016).

**RESULTS AND DISCUSSIONS**

Iron Content in the fortified Rice
Iron content in these samples was in the range of 35-45 ppm. For further study, three lots of paddy (50 kg each, total 150 kg) of Sampada, which is a known rice variety, were fortified. Iron content in this bulk sample was 35-40 ppm. This process was found better than the other reported methods (Chanakan et al., 2011). The loss of iron during washing with water or cooked in excess of water is comparatively less as during parboiling iron gets absorbed inside the grain.

Sensory Evaluation and Consumers Acceptability
There was no significant difference in overall acceptability between the six products of normal and iron fortified rice. However a significant (p<0.01) difference existed within the products of normal and iron fortified rice. The products vegetable Biryani (VBI) prepared with iron fortified rice scored the highest (6.26±0.70), thus, it was most acceptable product prepared with iron fortified rice. Hence Vegetable Biryani was selected to carry out the consumer acceptability study.

The results showed that there was no significant difference in the sensory attributes of the product prepared with normal rice and iron fortified rice. The iron fortified rice product was well accepted by the respondents (n=100).

**Effect of Iron-fortified Rice on Haemoglobin level**
The results indicate that there was no significant change in the haemoglobin level of the subjects in control group, whereas, in case of experimental group, the haemoglobin level increased significantly (p<0.01) from the 0th day to 60th day in moderate (Hb 8.0-10.9 g/dl) and severe anaemic (Hb<8.0g/dl) subjects. The haemoglobin level also increased from 0th day to 60th day in the experimental subjects with mild anaemia (Hb 11.0-11.9g/dl), but the increase was not statistically significant. The mean haemoglobin level in the mild anaemic experimental subjects was 11.75 ± 0.21 g/dl at baseline (0th day), which increased to 11.83 ± 0.46 g/dl on 60th day. The mean haemoglobin level increased from 9.25 ± 0.73 g/dl on 0th day to 10.83 ± 1.40 g/dl on 60th day and 6.77 ± 0.28 g/dl on 0th day to 10.36 ± 1.35 g/dl on 60th day respectively in cases of moderate and severe anaemic experimental subjects.

There are four types of rice fortification technology (Sajid et al., 2008) being commercially used namely

1) Hot Extrusion, 2) Cold Extrusion, 3) Coating process, and 4) Dusting process. Our technology of rice fortification which is done by parboiling process is simple and economically cheaper than the above existing technology because

1) All the existing technologies require specific type of equipments/machine
2) Hot extrusion process involves multiple steps and is very expensive
3) Cold extrusion process also involves multistep and produces opaque and slightly off-colour products.
4) Coating process produces kernels of distinctive colour, smell and taste which may not be liked by consumers
5) Kernels obtained from the Dusting process lose the micronutrients when rinsed or washed with before cooking.

Hence it can be concluded that the rice fortified with NaFeEDTA can be an effective solution to prevent the enormous prevalence of anaemia and the process of fortification is simple and cost effective.

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REFERENCES