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COMBATING IRON DEFICIENCY ANAEMIA THROUGH FOOD-TO-FOOD FORTIFICATION: RECIPE DEVELOPMENT, IRON BIOAVAILABILITY AND EFFECT OF SUPPLEMENTATION

Monika Jain[1]
Department of Food Science and Nutrition, Banasthali Vidyapith, Rajasthan

[1]Corresponding Author: drmonikajain2000@gmail.com

ABSTRACT

This study was undertaken for iron rich recipe standardization using food-to-food fortification and comparison of impact of supplementation of iron enriched food product and intermittent medicinal iron as well as sustainability. Recipes were standardized after suitable addition of iron rich ingredients along with bioavailability enhancing processing technique and analysed for acceptability and *in vitro* iron bioavailability. Haematological assessment of subjects (8-10 years girls; n=111) included estimation of haemoglobin (Hb), red cell indices, serum iron, total iron binding capacity (TIBC), transferrin saturation and ferritin. Anaemic subjects were divided into three groups- AE1: iron folic acid syrup twice weekly; AE2: daily supplementation of four niger seed and defatted soyflour biscuits plus two lemons and AC remained unsupplemented. Post intervention data was collected after an intervention period of 120 days. Follow up for Hb was done four months after cessation of supplementation. Out of iron rich biscuit, *idli*, *handwa* and soy chat, niger seed added soy biscuits had best acceptability and 10.8 mg% iron. Twice weekly medicinal iron supplementation was effective ($p<0.05$) in raising Hb and building iron stores. Iron rich food supplementation also improved haematological profile ($p<0.05$) but to a lesser extent. The impact of iron rich food supplementation on Hb sustained for four months while that of medicinal iron did not. Effect of food supplementation is sustainable; therefore, this strategy seems to hold more potential to control anaemia in school girls.

KEYWORDS: Anaemia, fortification, haemoglobin, iron, iron deficiency, supplementation.

INTRODUCTION

Iron plays a vital role in physical and cognitive development of growing children and adolescents. Despite the potentially long term adverse developmental consequences of iron deficiency anaemia (IDA) in children, the problem has largely been neglected and few countries have a strategy for the control of IDA in children (Draper and Arthur, 2001). Even researchers have focused narrowly on infancy, young childhood and maternal outcomes with respect to iron deficiency (ID) and anaemia. Of a review of over 500 studies on anaemia, only 39 included adolescents and a mere handful considered the status of male adults or school aged children (Kurz, 1996). A narrow focus on infants and lactating women also risks ignoring problem in the elderly, non pregnant women, adolescent and school age girls (Webb et al., 2007).

Studies indicate that iron supplementation has positive effects on haemoglobin (Hb) levels and growth (Kanani and Poojara, 2000; Lawless et al., 1994). It is worthwhile to explore if this impact will be seen with intermittent iron supplements in young girls entering puberty. Since iron supplementation programmes have had little reported success in reducing anaemia, interest is turning to food based approaches that have higher potential for achieving far-reaching and long lasting benefits for the control of iron deficiency. Food-based approaches aim at improving nutrition by increasing the availability and consumption of a nutritionally adequate and micronutrient rich diet made up from a variety of available foods. Food based approaches are recognised as an essential part of an urgently needed more comprehensive strategy to combat iron and other micronutrient deficiencies. Tandon (2002) opines that from “pill” to natural food is a difficult challenge but should be considered as the best and most natural solution to the problem of iron deficiency in India.

Intake of iron rich foods has the potential of reducing iron deficiency. The iron from non animal foods generally has low bioavailability but can be significantly enhanced by adding foods rich in vitamin C. Other effective ways of increasing iron bioavailability include germination, soaking, fermentation and malting of grains, which activate phytases that breakdown phytic acid, the most important antinutrient that inhibits iron absorption. Ferritin, a major form of endogenous iron in food legumes such as soybeans, is a novel and natural alternative to such iron supplementation strategies where effectiveness is limited by acceptability, cost, or undesirable side effects (Theil, 2004). New thinking is emerging concerning fortification and enrichment. Fortification of a micronutrient-poor staple with a concentrated micronutrient-rich food is an under explored strategy with household/community-level income-generating and gender-empowering potential (Underwood, 1998). Some traditional household food preservation and preparation practices, such as fermentation (e.g. of fish, soy, and milk products), favour micronutrient retention or enhance bioavailability, particularly of iron, and are important components of a household food-to-food fortification strategy. There is a need for additional research to confirm the aforementioned observations, to explore on the manifestations of IDA in school aged girls, to evaluate the impact of alternative methods for delivering iron and to establish the feasibility and effectiveness of intermittent iron supplementation on haematological profile. Therefore, the objectives of this study were to develop food products rich in iron using food-to-food fortification, and conduct their sensory and nutritional analysis. The study also attempted to test the selected fortified recipes for *in vitro* iron bioavailability and compare the effectiveness of food and intermittent medicinal iron supplementation strategies in affecting haematological parameters in school age girls. The endeavour also encompassed observation of the sustainability of the effects of the two supplementation regimes.

MATERIALS AND METHODS

PRODUCT DEVELOPMENT

Idea generation and screening of ideas were the initial steps of product development using food-to-food fortification. After trials of fifty recipes product enrichment and prototype development was taken up for the recipes with higher acceptability. Two iron enriched variants each of biscuit, *handwa*, *idli* and soy *chat* were prepared. After a series of trials using ingredients in various proportions and adding different iron enriching products /methods, the concept of the enriched products took shape (table 1).

Table 1. Recipes standardized using food-to-food fortification

Recipe	Characterstics	Primary ingredient(s)	Iron fortifying ingredient(s)	Bioavailability enhancing processing
BISCUIT	Control	Refined wheat flour, semolina	-	-
	Variant 1	Refined wheat flour	DSF	-
	Variant 2	-	DSF, niger seeds	-
HANDWA	Control	Semolina	-	-
	Variant 1	Semolina	Soybean	Fermentation
	Variant 2	Semolina	Ricebran, cauliflower greens, bengalgram greens	Fermentation
IDLI	Control	Semolina	-	-
	Variant 1	Semolina	Soybean	Fermentation
	Variant 2	Parboiled rice, dehusked black gram dhal	Soybean	Fermentation
SOY CHAT	Control	Soybean, tomato, guava	Soybean	-
	Variant 1	Soybean, tomato, guava	Soybean	Germination
	Variant 2	Soybean, tomato, guava	Soybean	Germination

Defatted soy flour (DSF)/ gram flour and niger seeds made the grade for addition to biscuits for enrichment. *Handwa* was enriched with soy flour/ rice bran/ cauliflower greens/ bengal gram leaves. Enrichment of *idli* was done with soybean (soaked/fermented). Soybean *chat* was prepared by varying the pre treatments, viz., soaking, germination and boiling. Enrichment with soybean in standard recipes was liked most in informal acceptability testing.

NUTRITIONAL AND SENSORY ANALYSIS

Standardised control and iron enriched recipes were estimated for moisture, ash, total iron (Wong's method) and bioavailable iron by the method of Narasinga Rao and Prabhavathi (1978). Sensory evaluation included selection of semi trained panel using triangle test. Control and iron enriched variants were subjected to 9 point hedonic test, paired comparison test and ranking test by a panel of 17 judges.

INTERVENTION

A pre- post- intervention trial along with a control group has been undertaken. The participants of the study were 8 to 11 year old school age girls residing in the hostels of *Banasthali Vidyapith*. After getting the consent from the authorities and the parents of the children, they were screened for Hb. Those having severe anaemia or having suffered a recent episode of malaria or having attained menarche were dropped. The complete data was thus obtained from 111 girls. On the basis of Hb values anaemic subjects (n=86) were divided into two experimental and one control group. After due consultation with medical gastroenterologist specializing in public health nutrition, the subjects in the experimental group 1 (AE1; n=30) were supplemented with iron (1066.66 mg ferrous ammonium citrate /100ml; elemental iron: 213.33 mg/100ml), folic acid (3.33mg/100ml), cyanocobalamin (50 µg/100ml) syrup twice weekly. Supplementation of 25 ml of the syrup provided 53 mg of elemental iron per week. DSF and niger seed added biscuits not only had high iron and high acceptability but also the qualities of ease of keeping and distribution. Therefore, these were selected for supplementation. Experimental group 2 (AE2; n=31) was to be supplemented with 2 niger seed biscuits and a lemon twice daily, after the 2 major meals. This intervention with 100 percent compliance was to provide approximately 45 mg of iron in a week. Control group (AC; n=25) remained unsupplemented. The initially non anaemic group comprising of 25 subjects was not intervened and served as Non Anaemic Control (NAC). Pre- and post- intervention data was collected before initiating and after completing supplementation of 120 days. A follow up was conducted 4 months after the completion of supplementation and all the subjects were appraised for Hb. *Haematological estimation*: It included estimation of Hb (cyanmethaemoglobin method), red cell indices namely, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) (using automated haemo analyser), serum iron and TIBC (using reagent kits based on Ramsay's method) and serum ferritin in one fourth of the subjects using ELFA technique. *Data analysis*: Statistical analysis was conducted using the statistical software Minitab® 15.1.0.0 (Minitab Inc.). Inferential statistics included hypothesis testing through student's and paired t test. The null hypothesis for the test was that the two population means are the same. Significance was defined as $p<0.05$. A one-way analysis of variance (ANOVA) was used to test the hypothesis that the means of several populations are equal. The null hypothesis for the test was that all population means (level means) are the same. In addition to evaluating whether all the level means are the same, Tukey's test was used to determine which level means are different when differences existed. Hypothesis testing was done at 95% confidence interval. Coefficient of variation (CV) was used to analyse the relative variation in the sensory evaluation of recipes.

RESULTS

BACKGROUND INFORMATION

The 8 to 11 year old subjects (mean age 9.9 years) were from varied backgrounds with respect to state of domicile, mother tongue, family composition but they had been staying together in the hostels of the institution at least for a year. Their eating pattern (lacto vegetarian) and lifestyles were also similar.

FOOD ANALYSIS

Moisture content of products ranged from 6.9 to 88.8 % (table 2).

Table 2- Nutritional analysis of control recipes and their iron enriched variants

Food product	Type	Moisture (g/100g)	Ash	Total iron	Soluble iron	Ionisable iron
			(g/100g)	(mg/100g)	(%)	(%)
Biscuit	Control	6.9	0.6	1.4	54.1	8.3
	Variant 1	7.2	2.9	5.9	80.0	21.1
	Variant 2	8.1	3.1	10.8	82.3	23.0

Handwa	Control	65.8	0.5	1.2	56.6	6.1
	Variant 1	88.8	0.4	4.8	63.3	15.1
	Variant 2	59.4	1.6	6.4	47.2	12.6
Idli	Control	61.7	0.8	1.3	56.0	6.3
	Variant 1	81.8	3.5	5.5	70.2	5.0
	Variant 2	86.6	4.8	8.7	63.5	15.2
Soy chat	Control	54.3	3.8	7.7	79.0	17.0
	Variant 1	68.4	6.0	9.3	77.7	25.2
	Variant 2	63.6	4.6	8.1	68.5	23.2

Biscuits had the lowest moisture percentage and all the three types had moisture below 10%. *Handwa*, *idli* and soy *chat* had moisture percentage between 54 and 89. Ash content of various recipes ranged from 0.4 to 6.0 g/100g. Ash content in control recipes was lower than their iron enriched variants. The total iron content varied from as low as 1.3 mg/100g in *idli* (control) to 10.8 mg/100g in niger seed biscuits (variant 2). This was followed by soy *chat* (9.3 mg/100g) wherein the soybeans had been germinated. Soybean added fermented *idli* had an iron content of 8.7 mg/100g and rice bran and cauliflower greens added *handwa* had 6.4 mg iron per 100g. The highest soluble iron percentage at pH was observed in biscuits. Whereas the control biscuit had 54% soluble iron, the variants had percentages above 80. Ionisable iron percentage ranged from 5 to 25. The recipes in which soybean was an ingredient had relatively higher ionisable iron percentage. The values of ionisable iron also enhanced on processing; germinated soy *chat* and fermented *idli* had higher ionisable iron percentage in comparison to their respective controls.

SENSORY ANALYSIS

In hedonic test, control biscuit had a mean of 8.9 (table 3). The likeability of variant 2, niger seed and DSF containing biscuit was also very high (8.7). The hedonic test scores of control and niger seed biscuits were not significantly different from each other. Control *handwa* had extremely good acceptability (8.7), closely followed by its variant 1 (8.5). ANOVA points out to a significant difference in the mean scores.

Table 3 Hedonic test scores* of control recipes and their iron enriched variants

Recipe→	**Biscuit**		**Handwa**		**Idli**		**Soy chat**	
	Mean˜±SD	CV	Mean˜±SD	CV	Mean˜±SD	CV	Mean˜±SD	CV
Type↓								
Control	8.9±0.24	2.71	8.7±0.43	4.99	8.4±0.50	6.03	8.0±0.35	4.42
Variant 1	8.4±0.62	7.37	8.5±0.62	7.32	7.8±0.52	6.76	7.8±0.69	8.84
Variant 2	8.7±0.56	6.42	7.1±0.52	7.37	8.4±0.71	8.47	8.5±0.51	6.03

˜Mean of 17 values, *Maximum possible score: 9

Mean hedonic test scores of both control and fermented *idli* with rice, dhal and soybean were 8.4. ANOVA and Tukey's test indicate a significant difference in scores of variant 1 in comparison to control and variant 2 respectively. Soy chat made of germinated and sauted soybean had mean of 8.5 which was higher than that of control (8). The difference between the means was significant as inferred through ANOVA. Variant 2 was significantly better than control and variant 1 as revealed by Tukey's test. Control *bhakhri* which was made of *bajra* flour was liked highly by 16 judges. Ferrous citrate fortified *bhakhris* (V1 and V2) had moderate to high acceptability. Acceptability of ferrous fumarate fortified variants (V3 and V4) was still lower. Least acceptable were ferrous sulphate fortified variants (V5 and V6). In paired comparison test all judges marked control as positive for appearance, flavour, taste and after taste when compared with variant 1. The difference was statistically significant. No significant difference existed in either of the attributes between control biscuit and variant 2. Control recipe of *handwa* was marked better in every attribute by larger number of judges, when compared with variant 1. Yet the difference between the numbers of positives was not significant in any attribute. In comparison test of control and variant 2, all the judges marked the former better in flavour, taste and after taste. Variant 2 of *idli* did not differ significantly from control in either of the attributes. Variant 1 of soy *chat* was significantly better than control in appearance with all the judges marking the former as positive. The iron enriched variants of all recipes were subjected to ranking test in order to select the best in terms of acceptability. Lowest total was obtained by variant 2 of biscuit signifying that most of the judges put it at higher rank.

BASELINE CHARACTERSTICS

The Hb values ranged from 7.8 to 12.9 g/dl, at baseline. The distribution of subjects as per deficient and normal values of Hb indicates that 77% subjects were anaemic. Forty six per cent subjects had mild anaemia and 32% had moderate anaemia. Statistically, the difference between Hb of anaemics and non anaemics was significant. Mean MCV, MCH and MCHC of anaemic subjects were 73.0 fl, 27.6 pg and 31.3% respectively. The means of same indices in non anaemic group were 88.0 fl, 28.8 pg and 32.8% respectively. Serum iron and TIBC mean values were 55.5 and 776.9 µg/dl in moderately anaemic subjects; 86.8 and 663.9 µg/dl in mildly anaemic subjects; 151.5 and 594.2 µg/dl in non anaemic subjects. Per cent transferrin saturation means were 7.2, 13.2 and 26.2 in moderately anaemic, mildly anaemic and non anaemic groups respectively. Mean serum ferritin was 17.1 µg/l in those suffering from moderate anaemia, 18.8 µg/l in mildly anaemics and 50.2 µg/l in those who were not anaemic. There was a significant difference ($p < 0.05$) between anaemic and non anaemic group in all the haematological parameters.

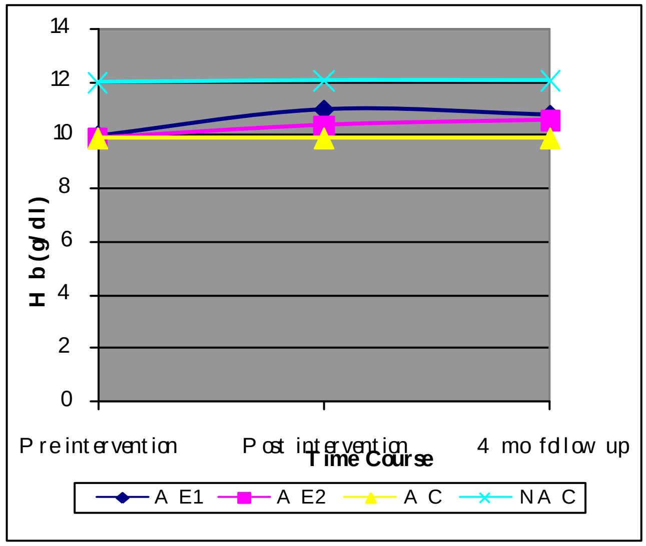

Figure 1Time course changes in the haemoglobin level of the various intervention and non intervention groups

IMPACT OF INTERVENTION

While the mean Hb of anaemic intervention groups was approximately 10g/dl at baseline, it was 12.1 g/dl in the non anaemic control group (table 4).

Twice weekly medicinal iron supplementation to AE1 resulted in a hike in Hb. The mean increment in Hb was of 1.0 g. A mean increment of 0.5 g/dl of Hb was observed in AE2 group wherein iron rich biscuits and lemons were supplemented daily. Although there was an increment in mean Hb of both AE1 and AE2, at post intervention stage there existed a significant difference in their mean Hb values. No significant changes were recorded in Hb levels of anaemic and non anaemic control group ($p>0.05$). Mean Hb of AE1 and AE2 which were at par with AC at baseline, were significantly different than control at post intervention stage. Significant difference of AE1 and AE2 with NAC persisted at the completion of intervention. MCV of AE1 increased from 73.6 to 77.7 fl and that of AE2 increased from 72.9 to 74.5 fl after supplementation. MCH of AE1 increased from 28.1 to 29.6 pg and that of AE2 increased from 27.6 to 28.2 pg at post intervention stage. MCHC of AE1 increased from 31.5 to 33.1% and that of AE2 increased from 31.5 to 32.5% at post intervention stage. All the changes were significant in the experimental groups but not in non anaemic controls. ANOVA pointed to a significant difference in the mean serum iron and TIBC of the four groups at baseline.

Table 4- Impact of intervention on haemoglobin, serum iron, TIBC and transferrin saturation

	Groups→	AE1 (n=30)	AE2 (n=31)	AC (n=25)	NAC (n=25)
		(Mean±SD)			
Haematological Parameters	**Intervention stage↓**				
Haemoglobin	**Pre**	10.0±0.66	9.9±0.63	9.9±0.85	12.1±0.37
(g/dl)	**Post**	11.0±0.54	10.4±0.58	9.9±0.82	12.1±0.37
Serum iron	**Pre**	74.5±23.67	72.1±21.50	75.8±29.17	151.5±15.60
(µg/dl)	**Post**	83.3±21.31	77.6±20.75	75.9±28.69	151.6±15.54
TIBC	**Pre**	714.1±75.60	717.2±93.30	696.0±95.60	594.2±83.50
(µg/dl)	**Post**	673.2±94.40	696.6±98.20	696.8±95.70	593.5±83.30
Transferrin	**Pre**	10.6±3.71	10.4±10.77	11.3±5.17	26.2±5.77
Saturation (%)	**Post**	12.9±4.91	11.6±04.31	11.3±5.10	26.2±5.77

Tukey's test revealed that mean of non anaemic group was significantly different than the remaining 3 anaemic groups. In AE1, mean serum iron rose from 74.5 to 83.3 µg/dl, TIBC decreased from 714.1 to 673.2 µg/dl and transferrin saturation increased from 10.6 to 12.9% at post intervention stage. The change in serum iron was from 72.1 to 77. 6 µg/dl, in TIBC from 717.2 to 696.6 µg/dl and in transferrin saturation from 10.4 to 11.6% in AE2 after the completion of supplementation. The changes in AE1 and AE2 were significant and that in AC and NAC were non significant. Medicinal iron supplementation led to a rise in serum ferritin from 18.2 to 24.9 µg/l and the increase was from 15.2 to 19.1 µg/l in iron and vitamin C rich food supplemented group.

SUSTAINABILITY OF SUPPLEMENTATION EFFECTS

After the completion of supplementation and post intervention stage data collection, no further intervention was given to the subjects. When 120 days elapsed, a re assessment of Hb was conducted in all 4 intervention groups. As mentioned earlier, the mean change in Hb was of 1.0 g/dl after completion of twice weekly medicinal iron supplementation. Four months hence, the Hb dropped by 0.2 g/dl (figure1). This change was statistically significant ($p<0.05$). Iron and vitamin C rich food supplementation brought about an increase of 0.5 g/dl. When 120 days elapsed without any intervention, a further increase of 0.2 g/dl of Hb was noted in AE2. This increase was statistically significant. The change in AC and NAC (post intervention vs 4 months after intervention) was non significant. Four months after the cessation of intervention, there was no significant difference between Hb of AE1 and AE2 (t cal=1.41; p=0.165). The difference between anaemics and non anaemics persisted.

DISCUSSION

Low dietary intake of iron is one of the leading causes of high prevalence of IDA. Although cereals are fair source of iron, yet other iron rich foods need to be included into the diet so as to fulfill the iron requirements. Food to food fortification is a simple and effective way of iron enrichment. Iron rich food sources when added to a recipe, enhances its iron content. This has been observed from the results of the present study wherein addition of soybean, cauliflower greens, rice bran to common recipes increased their iron content. Such attempts have been made by other researchers too. Plahar et al., (2003) enriched the existing traditional maize flour based weaning food by the addition of roasted peanuts and soybean. Roasting and extrusion were used in the innovative weaning food. Iron content increased and was found to be between 4.1 to 5.7 mg% in various combinations. The nutrient compositions of eight multimixes formulated for use as complementary foods from processed soybeans, cowpeas, maize, sorghum, yams, cocoyams, plantains and sweet potatoes were examined. The iron content of mixture ranged from 2.37 to 3.66 mg/100g (Nnam, 2000). Two weaning formulations were designed. The ingredients incorporated into these formulations were maize, cowpeas, peanuts, soybeans and soybean oil; iron ranged between 3.14 to 5.66 mg/100g (Mensa-Wilmot et al., 2003).

The deficiency of iron is usually due not to the absolute lack of the element in the diet but rather to its poor bioavailability. Iron availability is also influenced by the degree of iron deficiency of the individual, the adequacy of intestinal secretions, and the various components in foods that inhibit or enhance iron absorption. The majority of the population of most developing countries including India, rely on plant foods to provide their protein and energy requirements. The availability of iron from these plant staples is very low. Traditional processing procedures can improve the availability of iron from a wide range of foods which were used in standardization of iron enriched recipes in this endeavour. The mineral content of legumes is generally high, but the bioavailability is poor due to the presence of phytate, which is a main inhibitor of Fe and Zn absorption. Some legumes also contain considerable amounts of Fe-binding polyphenols inhibiting Fe absorption. Efficient removal of phytate, and probably also polyphenols, can be obtained by enzymatic degradation during food processing, either by increasing the activity of the naturally occurring plant phytases and polyphenol degrading enzymes, or by addition of enzyme preparations. Biological food processing techniques that increase the activity of the native enzymes are soaking, germination, hydrothermal treatment and fermentation (Sandberg, 2002). The use of these treatments in the present investigation must have been responsible for enhanced ionisable iron content in variants of idli and soy chat. Traditional food preparation processes such as soaking, germination and fermentation can also activate native phytases and substantially degrade phytic acid (Hurrell, 2003) thus increasing iron bioavailability. Addition of compounds to the food that prevent phytate-mineral binding like ascorbic acid (Davidsson et al., 1994) and sodium EDTA (Hurrell et al., 2000) improve iron absorption. The percentage of ionisable iron at pH 7.5 was higher in biscuits that contained DSF. Soy chat which was prepared by soaking and germination also had high ionisable iron percentage which goes with the recommendations that soaking, germination and fermentation should be encouraged so as to enhance iron bioavailability. Incorporation of DSF in a small quantity improves the protein quality of cereal based products without causing significant difference in the acceptability of the developed product. It was observed that the flavour and taste of full fat soy flour incorporated biscuit at 5% level was comparable with the biscuits prepared from refined wheat flour (Mridula and Wanjari, 2006). Biscuits were prepared from flour blends containing varying proportions of bajra flour and fortified with 5% DSF. Overall acceptability was good of and mean hedonic scores increased with the decreasing proportion of bajra flour (Mridula and Gupta, 2008). Blends of soybean flour (SF) and cassava flour (CF) were prepared on a replacement basis (CF/SF, 100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 0:100). Biscuits were produced from the blends and evaluated for their sensory properties. Sensory evaluation indicated that there were no significant differences in colour, texture, flavour, taste and overall acceptability of the flour blend biscuits. At 50% level of soya flour incorporation, biscuits had higher scores for all the sensory attributes evaluated. Above this level, biscuits received lower sensory scores (Akubor and Ukwuru, 2003). Even in this project, the DSF incorporated biscuits used for supplementation in this study had high acceptability and were not found to be significantly different from control biscuits.

Intermittent iron supplementation has yielded encouraging results in bringing about a change in iron status in this study. At the end of 120 days supplementation period Hb, serum iron, TIBC and other haematological parameters showed an improvement in the twice weekly medicinal iron supplement group. No significant changes were noticed in the control group. Several other researchers have reported likewise. The effect of daily vs twice weekly iron supplementation on iron status was studied in preschool children with low iron status. For 8 weeks one group received a daily supplement of 30 mg Fe, while the other group received 30 mg Fe twice per week. Hb, serum ferritin and protoporphyrin increased significantly in both groups. It was concluded that in preschool children with low iron status, twice weekly iron supplementation has an effect on iron status similar to that of daily supplementation (Schultink et al., 1995). Other researchers have explored the effects of food supplementation on haematinic status of subjects. Study by Santos et al., (2007) evaluated the effectiveness of supplementation with ferrous sulphate and iron bis-glycinate chelate-enriched cookies on haemoglobin and serum ferritin levels among school children (7-11 years). The interventions showed a significant increase in Hb levels (1.1 g/dL) for children who received ferrous sulphate and 0.9 g/dl in those who received iron bis-glycinate chelate, although not significant in the inter-group comparison. A study was conducted on Moroccon school children to test the efficacy of double fortified salt (DFS) with iodine and microencapsulated iron (Zimmermann et al., 2003). At 40 week, mean Hb concentrations in the DFS group had significantly increased by 14 g/l and serum ferritin, transferrin receptor, and zinc protoporphyrin concentrations were significantly better in the DFS group than in the iodized salt group. The prevalence of iron deficiency anaemia in the DFS group decreased significantly from 35% at baseline to 8% at 40 week. The beneficial effect of iron rich food supplementation as discussed above, have been observed in the present research work also. Although only 2 out of 31 anaemic subjects became non anaemic post iron rich biscuit intervention but half of the moderately anaemic subjects progressed to a stage of mild anaemia. It is pertinent to explore the sustainability of the effect of supplementation. In this study, food supplementation strategy yielded better sustainability results than the pharmacological intervention. The Australian Iron Status Advisory Panel advocates dietary intervention as the first treatment option for mild iron deficiency (SF = 10 to15 µg/l). Iron deficient women of child bearing age having high iron diet produced smaller increase in SF than the medicinal iron supplementation group but the former continued to show improvement in Hb and SF during a 6 mo follow up period (Patterson et al., 2001). The long term effectiveness of micronutrient fortified biscuit supplementation programme to primary school children was evaluated over a period of 45 months. Iron status returned to pre-intervention levels after the school holiday break (van Stuijvenberg, 2005). In this study, the Hb, in the medicinal iron supplemented group decreased at a 4 month follow up post supplementation. On the other hand, Hb continued to rise at a small pace in iron rich food supplemented group. This suggests that the effects of food supplementation, although quantitatively low, are able to sustain themselves even after cessation of supplementation which is not the case for medicinal iron supplementation. This observation puts fortified food supplementation over and above medicinal iron supplementation.

CONCLUSIONS

Food- to-food fortification is a promising strategy to combat the highly prevalent problem of iron deficiency and anaemia in vulnerable groups. Although intermittent iron supplementation is an effective strategy, fortified food supplementation takes an edge over it with respect to sustainability of effects. Schools can serve as channels for reaching the susceptible segments, i.e., children of various age groups and fortified food based intervention can be made a part of school feeding programmes. If the school going children are not well nourished and in poor health at school, the synergistic relationship between deprivation, poor health and malnourishment dilutes the benefits of any investments in education. Efforts are needed to eradicate iron deficiency to realise the potential of school children to become productive adults.

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