

Improving bioavailability of iron in Indian diets through food-based approaches for the control of iron deficiency anaemia

Prevalence and effects of iron deficiency anaemia in India

Iron deficiency anaemia (IDA) is a significant public health problem in India. National and regional surveys indicate that the prevalence of anaemia could be as high as 74 percent in children below three years of age, 85 percent in expectant mothers and 90 percent among adolescent girls in some population groups (MOHFW, 1998–1999; ICMR, 2001). In the slums of Bombay anaemia was found to be present in 70 percent of women over the age of 70, 52 percent of women over the age of 60 and 38 percent of men. The prevalence of anaemia was highest among those with severe malnutrition (ACC/SCN, 2000). IDA in infants and children is associated with impaired physical and cognitive development, and in adults with reduced work capacity and hence productivity,

overall lowered resistance to disease and increased morbidity and mortality. In women, IDA is also associated with adverse pregnancy outcome. It has been estimated that iron deficiency costs India about 5 percent of its gross national product annually from loss of lives, resources and productivity (Sanghvi, 1996).

The main reasons for IDA have been determined to be inadequate intake of iron, low bioavailability (1–6 percent) of dietary iron from plant foods (Narasinga Rao *et al.*, 1983) due to inhibitory factors, low levels of absorption enhancers in the diet, repeated pregnancies, increased needs during growth and development among children and adolescents, parasitic infestations and chronic blood loss. Poverty compounds these factors through inadequate access to dietary diversity, safe water, knowledge about safe food-handling and proper feeding practices (FAO/ILSI, 1997).

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The national goal and approaches to controlling IDA

The National Tenth Plan has set the goal of reducing the prevalence of anaemia by 25 percent among children and pregnant and lactating women (Government of India, 2002). National programmes and institutional approaches are being undertaken to achieve this goal.

The major approaches to controlling IDA, which are not mutually exclusive, are medicinal supplementation with iron and folic acid and food-based approaches, i.e. dietary diversification and fortification of foods, both complemented by programmes to counter parasitic infestations. While supplementation with iron is considered necessary for groups at high risk as a short-term emergency measure, it fails to address the root causes and cannot provide the overall long-term benefits of economy and sustainability. Evaluation studies of India's nationwide and long-standing supplementation programme showed irregular supplies, non-compliance by the beneficiaries, poor counselling, etc. As such, the supplementation strategy has proved to be inadequate (Vijayaraghvan, 2002).

Comprehensive review of food-based approaches

Food-based approaches to addressing IDA in India are being promoted, but information on which and to what extent food combinations would improve the bioavailability of dietary iron is fragmentary. Long-term controlled consumption and feeding studies are lacking owing to the difficulty and costs of dealing with several variables in large populations. Several experimental studies on the availability of food iron and related aspects have been reported, which showed the possibility of assessing how to improve the bioavailability of iron in plant foods (Allen and Ahluwalia, 1997), which should reduce the prevalence of IDA in the long run. With this objective, a

comprehensive review was carried out that attempted to highlight how food-based approaches could improve the bioavailability of Indian diets. The review included food and nutrient intake (especially haematinic nutrients such as iron, folic acid, vitamin A and protein) by the Indian population, factors influencing the bioavailability of food iron, cooking and processing methods and other factors particularly relevant to the Indian context. Over 420 references were reviewed, but only the most relevant research studies are reported here. On the basis of the review, some suggestions are given for improving the bioavailability of iron from Indian diets to improve iron nutrition.

Food and nutrient intake: patterns and levels

Surveys have shown that cereals form the major staple food and bulk of the diet of individuals in all the states studied. Millets are consumed in some states. Consumption of pulses, green leafy vegetables (GLV), milk, fruits and fats and oils was inadequate. The average consumption by adult females (sedentary) of cereals and millets (389 g) was about 95 percent of the recommended dietary intakes (RDI) of 410 g. Barring roots and tubers and other vegetables, the intake of all the other

foods was lower than the suggested intakes. The deficit with respect to GLV was the highest of all the food groups. The intake of cereals and millets among expectant mothers was comparable to the RDI and that of nursing mothers was higher than the RDI. The intake of all other foods was much lower than the RDI. No additional amounts were consumed to meet the increased needs of pregnancy.

Among children, the median intake of all the nutrients was low compared to the recommended dietary allowances (RDAs). The intake of micronutrients such as iron, vitamin A, riboflavin and folic acid was 40–60 percent of RDA among adolescent girls. However, the mean intake of ascorbic acid among adolescent girls and boys was 32–40 mg compared with the RDA of 40 mg. Among adults, nutrient intakes were close to the RDA levels except for iron, vitamin A and riboflavin (vitamin B₂). Intake of energy and all the nutrients was less than the RDA among expectant and nursing mothers (NNMB, 2002).

Food consumption in India is varied and influenced by regional, ethnic, cultural, income and agricultural production differences. The amounts of animal foods (meat, fish, and eggs) varied from 0 g (Haryana and Tamil Nadu) to 193 g (Arunachal Pradesh), and show the wide discrepancy among populations

TABLE 1

Women's food consumption: percent distribution of married women by frequency of consumption of specific foods, India, 1996–99

TYPE OF FOOD	FREQUENCY OF CONSUMPTION (% OF WOMEN)					TOTAL
	Daily	Weekly	Occasionally	Never	Missing	
Milk or curd	37.5	17.4	34.1	10.9	0.0	100.0
Pulses or beans	46.8	40.8	11.6	0.6	0.0	100.0
Green leafy vegetables	41.8	43.4	14.3	0.4	0.0	100.0
Other vegetables	65.1	28.0	6.6	0.2	0.0	100.0
Fruits	8.1	24.9	62.2	4.7	0.1	100.0
Eggs	2.8	25.0	37.9	34.2	0.0	100.0
Chicken, meat or fish	5.8	26.1	37.3	30.8	0.0	100.0

SOURCE: MOHFW, 1998–1999.

with respect to dietary sources of bioavailable iron (FAO, 1998).

The National Family Health Survey (MOHFW, 1998–1999) asked a sample of married women to specify the frequency (daily, weekly, occasionally or never) of the various types of foods that they consumed. Table 1 shows that there are substantial differentials in food consumption levels of different food groups. Age does not play an important role in women's consumption patterns. Women in urban areas are more likely than those in rural areas to include every type of food in their diet, particularly nutritious foods such as fruits and milk or curd. Illiterate women have poorer and less varied diets than literate women.

The low-income population consumes only two meals a day, comprised mainly of wheat or millet chapatti (an unleavened bread prepared on an iron plate) or rice, with tea, pickles, onion, salt and chillies, vegetables or pulses. The middle- and high-income populations generally eat three meals a day. As income rises, the intake of foods such as milk, fruits, vegetables and meat (if accepted culturally) increases. The intake of convenience foods also increases. The pattern is shown in Table 2.

Factors influencing dietary iron absorption

The bioavailability of dietary iron is the proportion of iron that is actually available for absorption and utilization by the body. As seen in Box 1, the bioavailability of food and dietary iron is influenced by certain factors, some of which are briefly described below.

Haem and non-haem iron. Food iron is classified as either haem iron (the iron from meat, poultry and fish), or non-haem iron (from cereals, pulses, legumes, fruits and vegetables). In humans, haem iron is well absorbed and its absorption varies little with the composition of the meal. Absorption is inversely related to the quantity of iron stores in the body, i.e. absorption ranges from 15 to 25 percent

TABLE 2

General food consumption pattern of low- and middle-/high-income populations

MEAL	FOOD CONSUMED	
	LOW-INCOME POPULATION	MIDDLE- /HIGH-INCOME POPULATION
Morning	Tea	Tea or coffee
Breakfast/brunch	Wheat and/or millet chapatti or rice + tea; vegetable; pickle; onion + salt + chilli; jaggery	Wheat parantha (sort of chapatti shallow fried on an iron pan) and/or millet chapatti + milk or curd (a type of yoghurt) and/or tea; rice + vegetable and/or pulse + banana or bread, butter, jam + fruit
Mid-morning	Tea (sometimes)	Tea or coffee + snack (biscuit, sandwich, samosa or pakora, or burger)
Lunch	–	Wheat and/or millet chapatti or rice + vegetable and/or pulse + salad and/or fruit
Mid-afternoon	Tea + sometimes a small bun or biscuit or savoury snack	Tea or coffee + snack (biscuit, sandwich, samosa or pakora, or burger)
Evening/dinner	Same pattern as for brunch, generally includes a vegetable or pulse	Same as lunch with more variety

BOX 1

Dietary iron absorption

FACTORS INFLUENCING DIETARY IRON ABSORPTION

Haem iron absorption

- Iron status of subject
- Amount of dietary haem iron, especially from meat
- Content of calcium in meal (e.g. milk, cheese)
- Food preparation (time, temperature)

Non-haem iron absorption

- Iron status of subject
- Amount of potentially available non-haem iron (adjustment for fortification iron and contamination iron)

BALANCE BETWEEN ENHANCING AND INHIBITING FACTORS

Enhancing factors

- Ascorbic acid (e.g. certain fruit juices, fruits, potatoes and certain vegetables)
- Meat or chicken, fish and other seafood
- Fermented vegetables (e.g. sauerkraut), fermented soy sauces, etc.

Inhibiting factors

- Phytates and other inositol phosphates (e.g. bran products, bread made from high-extraction flour, breakfast cereals, oats, rice [especially unpolished rice], pasta products, cocoa, nuts, soybeans and peas)
- Iron-binding phenolic compounds (e.g. tea, coffee, cocoa, certain spices, certain vegetables and most red wines)
- Calcium (e.g. milk, cheese)
- Soy proteins

SOURCE: FAO/WHO, 2002.

in normal subjects and 25 to 35 percent in iron-deficient subjects (Monsen, 1988). Baking and prolonged frying have been shown to reduce haem iron absorption by about 40 percent (Bothwell *et al.*, 1989).

The absorption of non-haem iron ranges from 2 to 20 percent. The specific rate of absorption of non-haem iron from plant foods is highly dependent on the effect of concomitantly ingested dietary

components (reducing substances such as ascorbic acid keep iron in the reduced ferrous form) and the amount of body iron stores. Severely iron-deficient individuals absorb non-haem iron at higher rates than those with normal iron levels (Monsen, 1988). Absorption was shown to be the highest (5–13 percent) in pregnant anaemic women (Dubey, 1994). In Indian studies, cooking of cereals and pulses was shown to cause a loss of 22–24 percent of their iron (Chiplonkar *et al.*, 1993). However, baking chapatti on an iron plate raised the iron content by 19 percent (Maingi and Narula-Sharma, 1972).

Phytates and polyphenols. The iron in Indian diets is mainly non-haem, the absorption of which is inhibited by food components, primarily phytates in grains, legumes, nuts, vegetables, roots and fruits, and polyphenols (tannates) in tea, coffee, vegetables, herbs and spices. Phytates can decrease non-haem iron absorption by 51–82 percent, and are found in higher concentrations in unrefined, non- or under-milled cereals than in refined, milled cereals. Fermentation can degrade the phytate and increase the bioavailability of iron in bread made from wholewheat flour (Brune *et al.*, 1992). Polyphenols in tea are strong inhibitors of iron absorption. For example, one large cup (250 ml) of black tea can inhibit non-haem iron absorption by approximately 50 percent even when drunk one hour after consuming the meal; it has no effect, however, when consumed between meals. This inhibition is strongly dose-related. The inhibiting effects can be reduced to some extent by serving tea with lemon or adding sufficient milk (100 ml) to the cup of tea. Some research from other countries indicates that black tea consumption does not cause IDA in people with diets containing a sufficient quantity of iron-rich foods. Iron absorption is affected less by coffee than tea (Brune *et al.*, 1989). To overcome the inhibitory effects, therefore, tea or coffee

should not be consumed with the main iron-containing meals.

Calcium. Calcium from dairy products interferes significantly with iron absorption of both haem and non-haem iron. Studies showed that about 30–50 percent more iron was absorbed when no milk or cheese was served with the main meal, which provided most of the dietary iron. The first 40 mg of calcium in a meal showed no inhibiting effect, whereas 300–600 mg of calcium inhibited iron absorption by 60 percent, which is the maximum inhibition of iron (Hallberg *et al.*, 1991; Hallberg, 1998). However, in an Indian study, the absorption of iron from cereal-based milk diets was shown to be better than that of meat or fish diets (Narasinga Rao *et al.*, 1983). The high iron availability of breast milk, which averages 50 percent (compared to 10–20 percent in cow's milk), is reduced when breast milk is taken together with cow's milk or weaning foods. Weaning foods should therefore be given separately from the breast milk (Chaudhary and Vir, 1994). Because calcium is also an important nutrient, it should be included in the diet for optimum health. Practical solutions for the competition of calcium with iron is to increase iron intake, increase its bioavailability or avoid taking calcium- and iron-rich foods at the same time.

Soybean. Soy protein in a meal reduces the amount of iron absorbed (Hallberg and Rossander, 1982). It has been found that the iron availability of an Indian meal is lowered more by adding soy milk than soy meal (Christian and Seshadri, 1989), but the effect of soybean on non-haem absorption has been controversial (Hallberg and Rossander, 1982). Some fermented soy sauces have, however, been found to enhance iron absorption (Baynes *et al.*, 1990).

Ascorbic acid. Ascorbic acid (vitamin C) is the most potent enhancer of non-haem iron absorption even in the presence of inhibitors such as phytates, tannates and

calcium. It can reduce food ferric iron to the better absorbed ferrous iron by 75–98 percent. In Indian studies, the addition of ascorbic acid to cereals and pulses enhanced the available iron (NIN, 1992). In cereal-based diets, absorption was the best for rice and vegetable combinations, which may result from ascorbic acid present in the vegetables (Narasinga Rao *et al.*, 1983). Children who consumed GLV once a week or more frequently had higher iron levels than non-consumers (Seshadri 1997). Daily intake of guava fruit with the two major meals by young anaemic women resulted in a significant increase in iron. In a community-level study, anaemic preschool children were given supplements of 100 mg synthetic ascorbic acid at each of their two daily meals for a period of two months; this improved their iron levels significantly and the prevalence of anaemia was reduced from 96 to 26 percent (Seshadri *et al.*, 1985). In regional meals, the addition of citrus fruit juices or a portion of potato, cauliflower or cabbage increased iron availability markedly (Seshadri, 1993; Chaudhary and Vir, 1994). The addition of 25 mg of ascorbic acid as lemonade consumed at two meals a day doubled the absorption of iron from a meal and improved the iron status of the participating women (García *et al.*, 1998). The comprehensive review has shown that a food source containing 50 mg of ascorbic acid consumed with the main meal (Cook and Monsen, 1977) providing most of the daily intake of iron enhances iron bioavailability significantly. Ascorbic acid also improves the availability of iron from fortified foods. The enhancing effect of ascorbic acid is dose-dependent, but little extra benefit is derived by increasing the intake of ascorbic acid beyond 100 mg in a meal. The influence of ascorbic acid is greatest on meals with low iron bioavailability, such as vegetarian meals.

Meat, fish, poultry. Meat and fish taken even in small amounts markedly improve the bioavailability of non-haem iron. The

addition of 90–100 g of meat, fish or poultry to the daily diet improves the bioavailability of iron significantly (Johnson and Walker, 1992), but because these foods are costly and culturally unacceptable, their use is uncertain. Moreover, a non-vegetarian diet containing 3 oz (approximately 85 g) of meat provided the same increase in non-haem iron absorption as 75 mg of ascorbic acid (Baynes and Bothwell, 1990).

Eggs are rich in iron content, but its bioavailability is poor. Studies showed that when two eggs were consumed per day there was a significant reduction in iron absorption from Indian meals (Kaur, 1981). Eggs are an important supplement in the diets of vulnerable mothers and children as they are a particularly good source of quality protein and are rich in vitamins and minerals (and even among vegetarians, they are accepted with less reluctance than meat or fish); thus the consumption of eggs may not be avoided. However, as a source of iron, eggs should be eaten along with a fruit or any other source containing 100 mg of ascorbic acid, or between meals.

Increasing intake and enhancing bioavailability of iron

A number of experimental studies on improving the bioavailability of iron have been conducted in different countries. However, very little research has been undertaken on methods to improve or optimize the bioavailability of iron from Indian diets. Furthermore, hardly any community or impact evaluation studies have been conducted on large Indian populations using food-based approaches. The following are some practical suggestions to provide a basis for such studies and community programmes.

The studies cited above have shown that the overall intake of iron from iron-rich foods needs to be increased to obtain the optimum level of RDA of iron in Indian population groups. This increase should be coupled with efforts to

combine appropriate foods in the diet to enhance the bioavailability of iron and reduce inhibitory factors.

Cereals and millets, pulses and legumes, GLV, nuts and oilseed are good sources of iron. Even without the haem iron found in fish or poultry, vegetarians are not at greater risk from iron deficiency than non-vegetarians (Miller, 1999). Plant foods can supply all the haematinic nutrients in adequate amounts with the exception of vitamin B₁₂ (cobalamin). The latter comes mostly from animal products and bacteria on plant foods.

Table 3 shows the iron content of plant foods that are consumed in India. Figures 1 and 2 show the fruits and GLV that can provide 50 mg equivalent

portions of ascorbic acid, which is essential as a bioavailability enhancer in Indian diets. Dietary consumption of iron and ascorbic acid could be increased by encouraging the production, processing, marketing and consumption of foods rich in these nutrients. Nutrition education could be a means to further this promotion process.

Vitamin C-rich foods must be consumed at the same meal that contributes the major part of daily dietary iron (Cook and Monsen, 1977). Furthermore, household processes such as germination, malting of grains/pulses and fermentation should be used to overcome phytates (Chaudhary and Vir, 1994) and enhance the ascorbic acid and

TABLE 3

Plant foods rich in iron

FOOD GROUP	FOOD	IRON, mg/100 g CONTAINED IN RAW EDIBLE PORTION
Cereals and millets	Bajra (Indian millet, <i>Pennisetum typhoideum</i>)	8.0
	Samai (little millet, <i>Panicum miliare</i>)	9.3
	Rice bran	35.0
	Wheat germ	6.0
Pulses and legumes	Soybean	10.4
	Chickpea, roasted	9.5
	Cowpea	8.6
	Lentil	7.6
	Peas, dry	7.1
	Horse-gram (<i>Dolichos biflorus</i>), whole	6.8
Green leafy vegetables	Amaranth, beet, cauliflower, chekkur manis, chickpea, cowpea, manathakkali, mint, mukarrate keerai, mustard, parsley, radish, shepu, turnip	15.6–40
Other vegetables	Lotus stem, dry	60.6
	Karonda, dry	39.1
	Sundakai, dry	22.2
	Onion stalks	7.4
	Plantain greens	6.3
Nuts and oil-seed	Garden cress seeds	100.0
	Coconut meal, deoiled	69.4
	Niger seeds	56.7
	Gingelly seeds	9.3
	Mustard seeds	7.9
Dry fruits	Pistachio nuts	7.7
	Blackcurrants	8.5
	Dates	7.3
Condiments and spices	Turmeric	67.8
	Mango powder	45.2
	Tamarind pulp	17.0
	Poppy seeds	15.9
	Black pepper, cloves, cumin	12.0

SOURCE: Gopalan *et al.*, 1989.

FIGURE 1

Ascorbic acid in one 50 mg portion of fruit

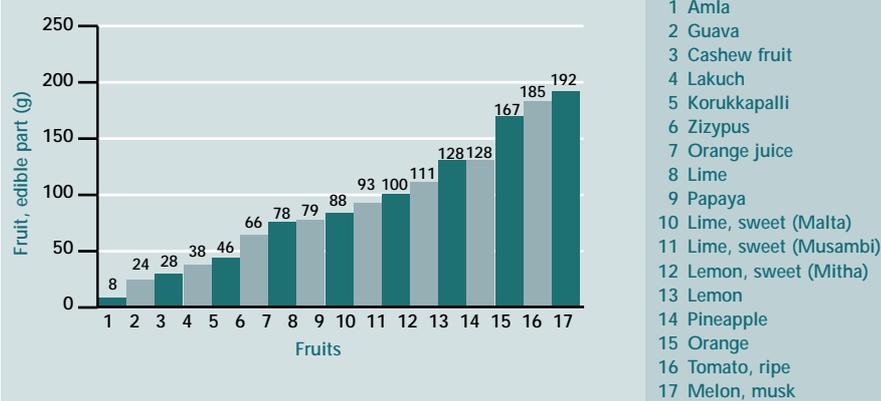
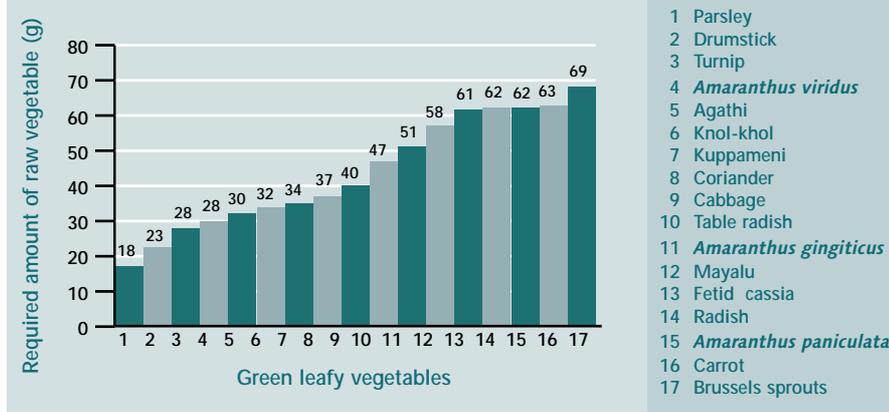


FIGURE 2

Ascorbic acid in one 50 mg portion of green leafy vegetables



B-vitamins. The presence of carotene in rice-, wheat- and corn-based diets improved iron absorption from one to more than threefold suggesting that both ascorbic acid and carotene (García-Casal *et al.*, 1998) prevented the inhibitory effect of phytates on iron absorption.

The values in the Figures and Table 3 have been calculated using the *Nutritive Value of Indian Foods* by Gopalan *et al.* (1989). The raw edible quantity of vegetables shown in Figure 2 would, however, need to be doubled to allow for about 50–75 percent loss of ascorbic acid in cooking (of all the methods of cooking, pressure-cooking retains the maximum amount). Cabbage, radish leaves and capsicum, after food-safety aspects have been observed, should preferably be eaten raw as salads to avoid loss of their vitamin C content.

Combinations and proportions of foods

On the basis of the factors influencing dietary iron absorption, a balanced vegetarian diet has been calculated for a woman of reproductive age. Table 4 shows the food groups and suggested daily intakes required to enhance its iron availability.

The suggested food combinations were formulated on the basis of using foods that are normally consumed, familiar, locally available and low-cost; containing enhancing factors and limiting inhibitors to the extent possible and providing an overall balanced diet to provide all the major nutrients required by the body (NIN, 1992–93). Tea with milk, lemon tea or herbal tea has been included between meals (and not with them) for better iron absorption from the

meals. Milk is taken at breakfast, in the evening or at bedtime and not with the main meals that contribute most of the daily iron intake. Milk intake may be increased to 400 ml per day provided it is distributed as suggested. Jaggery¹ instead of sugar is included, as it contains iron whereas sugar contains only a trace. Lunch and dinner can be interchanged depending upon the convenience of cooking. Early morning tea may be deleted and replaced with mid-morning or mid-afternoon tea. Meals may be cooked as one dish, e.g. *missi roti* (chapatti) comprising wheat or millet flour + pulse flour (chickpea) + GLV or gingelly seeds; or rice *khichdi* consisting of rice + green gram or chickpea split pulse + greens to improve nutritive value by supplementary action and to reduce cooking time. An example of a daily menu is given in Table 5.

Horticulture and small animal production

In order to increase iron consumption, improve its bioavailability and reduce IDA in India, it follows from the above presentation that, in general, more iron-rich foods, as well as foods enhancing iron bioavailability, need to be produced and distributed. Such action calls for the promotion of home/nutrition gardens and small animal products. Produce and animal foods are central to a food-based approach to improving overall nutrition and reducing micronutrient malnutrition, including IDA, because they provide multiple micronutrients (Hussain, 1998). In addition, such an approach would enhance the purchasing power of low-income households and vulnerable groups through the sale of foods not needed for home consumption (Tontisirin and Bhattacharjee, 1999). Evaluation studies in India showed such programmes to be successful in reducing the prevalence of micronutrient deficiencies (Vijayaraghavan, 2002).

¹ Jaggery is an unrefined sugar-cane product also known as turbinado sugar.

Nutrition education programmes will need to pay special attention to addressing the issue of iron deficiency within different population groups with varying dietary habits, socio-economic situations and nutritional and health status. The complexity of interactions between inhibitors and enhancers within diets needs to be translated into practical and simple messages with suggestions for optimal diets within a given cultural, agricultural and socio-economic environment. The objective is to improve the bioavailability of Indian diets to make headway for achieving the huge task of controlling IDA in the country.

Research needs

In order to further solidify the scientific basis for implementing large-scale food-based programmes to reduce IDA in India, the following areas of research may be identified.

- Long-term effects of the addition of food sources containing 50 mg and 100 mg of ascorbic acid to the existing meals, and of meals providing 12–15 mg of iron towards improving bioavailability of iron and the iron status in the anaemic Indian population.
- Effect of the addition of 50 g and 100 g of meat sources to existing meals (substituting the source of

protein in the particular meal) on the bioavailability of iron from meals and the iron status of different groups.

- Determination of quantities of inhibitory and enhancing factors present in individual meals/diets as consumed by the different socio-economic groups in anaemic and non-anaemic populations, and their iron status.
- Determination of the total and bioavailable contaminant iron² in the existing meals of the anaemic and non-anaemic population groups.
- Determination of the content and effects of lactic acid from curd (like yoghurt), and foods rich in citric acid and tartaric acid on the bioavailability of iron from foods and meals in Indian subjects.
- Determination of bioavailable iron in the diets of anaemic and non-anaemic women in relation to menstrual loss, infections and infestations such as hookworm or malaria.
- Determination of the availability of iron from fortified foods coming from the market.

² Iron from the soil may be present on the surface of foods; although the amount present may be small, it can be nutritionally significant.

TABLE 4

Balanced diet (vegetarian) for sedentary and moderately active women of reproductive age, suggested daily intake

FOOD GROUP	SEDENTARY	MODERATE
	QUANTITY, RAW EDIBLE PART (g)	
Cereals and millets	300	360
Pulses and legumes	60	75
Green leafy vegetables	75–100	75–100
Roots and tubers	75–100	100
Other vegetables	75–100	100
Fruits	75–100	75–100
Milk and dairy products	200	200
Sugar and jaggery	20	30
Fats and oils, visible	25	35
Condiments and spices	7–10	7–10

TABLE 5

Combinations and proportions of foods for daily consumption to enhance iron bioavailability: example number 1

MEAL	MENU	FOOD, RAW EDIBLE PART (g)
Early morning	Tea with milk/lime or herbal tea + biscuits (two) or rusk (one)	150 + 50/10 or 150
	Sugar	5
Breakfast	Stuffed chapatti or parantha Wheat + potato (boiled)	100 + 75
	Curd (like yoghurt) or milk	100
Lunch	Wheat + millet flours + cauliflower chapatti	50 + 50 + 50
	Lentil dal	30
	Cabbage, raw + tomato + lime juice salad	25 + 30 + 15
	Jaggery + gingelly seeds <i>gajak</i>	10 + 10
Mid-afternoon	Tea with milk/lime or herbal tea	150 + 50/10 or 150
	Sugar	5
	Snack (sweet or savoury), 1 or 2 pieces or equivalent	
Dinner	Rice <i>khichdi</i> :	
	Rice parboiled +	100
	Green gram split +	30
	Amaranth leafy vegetables	75
	Onion stalks	50
	Guava, orange or papaya	50

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Improving bioavailability of iron in Indian diets through food-based approaches for the control of iron deficiency anaemia

IRON DEFICIENCY ANAEMIA (IDA) is a significant public health problem in India. National and regional surveys of anaemia indicate that the problem could reach as high as 74 percent in children under 3 years of age, 85 percent in expectant mothers and 90 percent among adolescent girls in some population groups. IDA in infants and children is associated with impaired physical and cognitive development; in adults with reduced work capacity and, hence, productivity; with overall lowered resistance to disease and increased morbidity and mortality. In women, IDA is associated with adverse pregnancy outcomes. It has been estimated that iron deficiency costs India about 5 percent of its gross national product annually. The main reasons for IDA have been determined to be inadequate intake of iron, low bioavailability (1–6 percent) of dietary iron from plant foods due to inhibitory factors, low levels of absorption enhancers in the diet, repeated pregnancies, increased need for iron for growth and development among children and adolescents, parasitic infestations and chronic blood loss. Poverty compounds these factors due to inadequate access to dietary diversity, safe water, knowledge about safe food-handling and proper eating practices.

The major approaches to controlling IDA, which are not mutually exclusive, are medicinal supplementation with iron and folic acid and food-based approaches, i.e. dietary diversification and fortification of foods, both complemented by programmes against parasitic infestations. Food-based approaches to addressing IDA in India are being promoted, but information on how much and which food combinations will improve the bioavailability of dietary iron is fragmentary.

This article presents a comprehensive review highlighting how food-based approaches could improve bioavailability in Indian diets. The review includes: food and nutrient intake, especially haematinic nutrients (iron, folic acid, vitamin A, protein) by the Indian population; factors influencing the bioavailability of food iron; and cooking and processing methods that are particularly relevant to the Indian context. Over 420 references were reviewed, but only the most relevant research studies are reported here. On the basis of the review, some suggestions are given for increasing the bioavailability of iron from Indian diets so as to improve iron nutrition.

Amélioration de la biodisponibilité du fer dans les régimes alimentaires indiens par le biais d'approches de lutte contre l'anémie ferriprive fondées sur l'alimentation

EN INDE, L'ANÉMIE FERRIPRIVE est un sérieux problème de santé publique. Les enquêtes nationales et régionales indiquent que jusqu'à 74 pour cent des enfants âgés de moins de 3 ans, 85 pour cent des femmes enceintes et, dans certains groupes de population, 90 pour cent des adolescentes pourraient en souffrir. Chez le nourrisson et l'enfant, l'anémie ferriprive entrave le développement physique et cognitif; chez l'adulte, elle entraîne une réduction de la capacité de travail et, partant, de la productivité. Elle se traduit plus généralement par une baisse de la résistance aux maladies et un accroissement de la morbidité et de la mortalité, et peut aussi entraîner des complications pendant la grossesse. On estime que le problème coûte aux autorités indiennes quelque 5 pour cent de son produit national brut par an. Les principales causes de l'anémie ferriprive sont: des apports insuffisants en fer, une faible biodisponibilité (1-6 pour cent) du fer contenu dans les plantes vivrières due à des facteurs inhibiteurs, un régime alimentaire pauvre en substances facilitant l'absorption du fer, des grossesses répétées, les besoins accrus en fer des enfants et des adolescents en période de croissance et de développement, les infestations parasitaires et les hémorragies chroniques. La pauvreté aggrave ces facteurs dans la mesure où elle fait obstacle à la diversification des aliments et à l'accès à de l'eau salubre, et aux connaissances sur les méthodes de manipulation sans risque des aliments et sur les bonnes pratiques alimentaires. Les principales méthodes de lutte contre l'anémie ferriprive, qui ne s'excluent pas mutuellement, sont la

suplementación por el hierro y el ácido fólico y las estrategias basadas en la alimentación, a saber la diversificación y el enriquecimiento de los alimentos, que deben ser completadas por los programas de lucha contra las infestaciones parasitarias. Las estrategias de la anemia ferropénica basadas en la alimentación son actualmente alentadas en India. Sin embargo, la información sobre las cantidades y las asociaciones de alimentos que permiten mejorar la biodisponibilidad del hierro aportado por la alimentación permanecen fragmentarias.

El artículo hace un balance global de la situación y muestra cómo las estrategias basadas en la alimentación pueden contribuir a mejorar la biodisponibilidad del hierro en los regímenes alimentarios indios. El autor examina especialmente los aspectos siguientes: alimentación y aportes de nutrientes, especialmente hematínicos (hierro, ácido fólico, vitamina A, proteínas) de la población india; factores que influyen en la biodisponibilidad del hierro contenido en los alimentos; métodos de preparación y transformación especialmente adaptados al contexto indio. El autor ha pasado en revista más de 420 referencias bibliográficas, pero solo las más pertinentes se mencionan aquí. A la luz de este análisis, se recomiendan diversas soluciones de naturaleza para mejorar la biodisponibilidad del hierro en los regímenes alimentarios indios y, como consecuencia, los aportes alimentarios de hierro.

Mejora de la biodisponibilidad de hierro en la dieta de la India mediante enfoques basados en los alimentos para el control de la anemia por carencia de hierro

LA ANEMIA POR CARENCIA DE HIERRO (ACH) es un problema de salud pública importante en la India. Los estudios nacionales y regionales sobre la anemia indican que el problema podría afectar al 74 por ciento de la población infantil de menos de 3 años de edad, al 85 por ciento de las madres gestantes y al 90 por ciento de las adolescentes en algunos grupos de población. En los lactantes y los niños, la ACH está asociada con un desarrollo físico y cognitivo deficiente; en los adultos con una menor capacidad de trabajo y, por tanto, productividad; y, de forma general, con una menor resistencia a las enfermedades y una mayor morbilidad y mortalidad. En las mujeres, se asocia con malos resultados en el embarazo. Se estima que la carencia de hierro tiene en la India un costo equivalente al 5 por ciento de su producto nacional bruto. Se ha llegado a la conclusión de que las causas principales de la ACH son la ingesta insuficiente de hierro, la baja biodisponibilidad (1-6 por ciento) de hierro en la dieta procedente de alimentos vegetales como consecuencia de factores inhibidores, el escaso nivel de sustancias que favorecen la absorción en la dieta, los embarazos repetidos, la mayor necesidad de hierro para el crecimiento y desarrollo entre los niños y los adolescentes, las infestaciones parasitarias y la pérdida crónica de sangre. La pobreza agrava esos problemas debido a la insuficiente diversificación de la dieta y a la falta de acceso a agua potable, de conocimientos sobre la manipulación de los alimentos y de un comportamiento alimentario adecuado.

Los medios principales para hacer frente a la ACH, que no se excluyen entre sí, son la suplementación medicinal con hierro y ácido fólico y los enfoques basados en los alimentos, es decir, la diversificación de la dieta y el enriquecimiento de los alimentos, complementados con programas de lucha contra las infestaciones parasitarias. En la India se está promoviendo este tipo de enfoques, pero solo se dispone de información fragmentaria sobre la cantidad y combinación de alimentos que permitirá aumentar la biodisponibilidad de hierro en la dieta.

En este artículo se examina detalladamente cómo los enfoques basados en los alimentos pueden aumentar la biodisponibilidad en la dieta de ese país. En el examen se abordan la ingesta de alimentos y nutrientes, especialmente nutrientes hematínicos (hierro, ácido fólico, vitamina A y proteínas), por la población india; los factores que influyen en la biodisponibilidad de hierro en los alimentos; y métodos de cocinado y elaboración particularmente pertinentes en el contexto de la India. Aunque se examinaron más de 420 referencias, solamente se mencionan aquí los estudios más destacados. Basándose en el examen, se formulan algunas sugerencias para aumentar la biodisponibilidad de hierro en la dieta de la India con el fin de mejorar la nutrición en relación con el hierro.