

## The role of enriched foods in infant and child nutrition

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Since the last century, fortified and enriched foods are products whose original composition has been modified—through addition of essential nutrients—to satisfy specific population needs. For the fortification of foods to have a positive impact on nutritional status, the micronutrients added must be well absorbed and utilized by the organism (bioavailability). Diverse factors affect bioavailability, such as the nutritional status of individuals, the presence in the diet of substances which facilitate or inhibit its absorption, interactions among micronutrients, illnesses, and chemical characteristics of the compound used for fortification. In countries such as Chile, Venezuela and Mexico, important effects have been demonstrated in reducing iron deficiency anaemia in children under 5 years of age. In less than a decade, the salt iodization programme has also proven its effectiveness. Other programmes have fortified foods with Zn, vitamin A and folic acid, which are deficient in infants and children of many populations. In summary, food fortification is a low-cost, relatively simple strategy that may reach a wide range of people, and contribute to reducing the high prevalence of micronutrient deficiencies affecting children, especially in poor countries. The costs due to losses of human capital and their repercussions on health and future development are very high. Building links among academic researchers, politicians, food manufacturers and consumers is essential in order for food fortification to be efficacious and effective, and therefore should be considered as part of an integral strategy to combat micronutrient deficiencies.

### Fortified and enriched foods: Micronutrient deficiencies

Chronic malnutrition is responsible for millions of childhood deaths globally. Those who survive from chronic malnutrition are less likely to achieve a secure and productive life due to the greater morbidity and associated biological fragility (Svedberg, 2000).

Micronutrient deficiencies, i.e. vitamin and mineral deficiencies, is the most generalized form of malnutrition in the world, especially affecting women and children. It is estimated that between 4 and 5 billion people live with Fe deficiency, and an estimated 2 billion are calculated to have anaemia (UNICEF, 1998; World Health Organization/UNICEF/United Nations University, 2001).

### A global vision of chronic malnutrition and micronutrient deficiency anaemia, iron and zinc deficiencies

The prevalence of iron deficiency anaemia (IDA) among pre-school children in 1985 ranged between 25 and 50% in developing countries and between 2 and 8% in developed countries (De Maeyer, 1985). In 2000, the International Food Policy Research Institute did not find significant changes in the prevalence of anaemia over the previous 13 years. The prevalence of IDA in developing countries was 42%, and 17% in developed countries (United Nations Administrative Committee on Coordination/Sub-committee on Nutrition, 2000). It was higher in Africa and Asia where it reached 42 and 53%, respectively. In the American region, it was 30% in

Central American countries, and 26% in South America (Freire, 2003). The lowest prevalence (2–5%) is found in Europe and North America (United Nations Administrative Committee on Coordination/Sub-committee on Nutrition, 2000; Fig. 1). Among Spanish children aged between 6 and 36 months, the prevalence of IDA varies between 4 and 12% and among children and adolescents between 0 and 3%. This prevalence is superior to that registered in some countries where programmes have been developed to enrich foods with Fe, such as the Nordic countries and Italy, in which the prevalence of anaemia in childhood has been reduced to less than 1% (Anon., 1997).

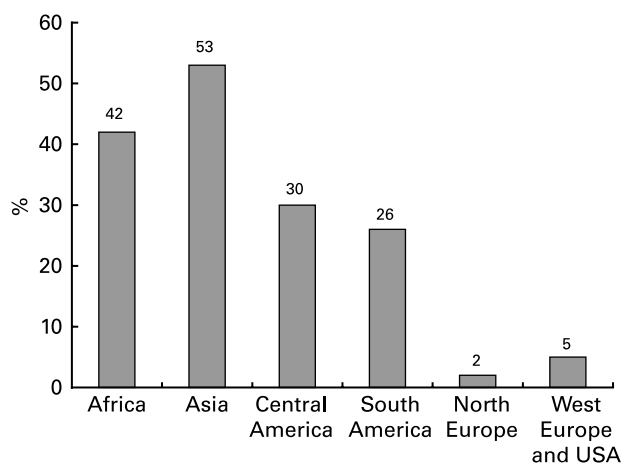
### Consequences of anaemia and iron deficiency

IDA has grave consequences especially for children under 5 years of age due to its effects on their physical and mental development and social performance. Children who suffered IDA during the first 2 years of life have lower school performance (Sayed *et al.* 1999). It is also associated with alterations in cellular immune response, which translates into higher morbidity rates by acute infectious diseases (Freire, 1998). It is also associated with decreased capacity to undertake activities requiring muscular resistance (Beard & Tobin, 2000).

It is important to note that the degree of anaemia or Fe deficiency suffered by women during pregnancy is proportional to the child's Fe reserve at birth and to the earlier

**Abbreviation:** IDA, iron deficiency anaemia.

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**Fig. 1.** Prevalence of anaemia in children <5 years old (United Nations Administrative Committee on Coordination/Sub-committee on Nutrition, 2000; Dietz, 2003).

appearance and degree of gravity of anaemia, which children often develop after 4 months of age (Menendez *et al.* 1994; Preziosi *et al.* 1997).

Micronutrient deficiencies participate directly or indirectly as causal factors of chronic malnutrition. This includes severe consequences for mental and physical growth and general health during childhood and for social performance in adult life, and the higher risk for perinatal morbidity and mortality. All of these negative effects have undeniable economic implications for society (Svedberg, 2000). In Venezuela, the costs implied by capacities lost due to IDA are close to 1% of the gross national product (Ross & Horton, 1998).

### Zinc deficiency

Zn participates as a cofactor in a variety of metabolic pathways: energy metabolism, protein synthesis and gene expression. Its deficiency therefore causes retarded growth and interferes with the correct development of neurological function during infancy (Brown *et al.* 2002). It also produces alterations in the cellular and humoral immune response. These immune alterations may be associated with the greater risk of diarrhoea and other infections, and increased mortality among Zn-deficient populations. The latter risks are reduced after supplementation with Zn. Zn deficiency is estimated to affect one-third of the world's population (Rivera *et al.* 2001; Hotz & Brown, 2004).

### Vitamin A, folate and vitamin B<sub>12</sub> deficiencies

Deficiencies of vitamin A and of folate have deleterious effects on physical growth, as demonstrated in both animals (West, 1991) and man (Hadi *et al.* 1999; Sedgh *et al.* 2000). Folic acid and vitamin B<sub>12</sub> deficiencies cause megaloblastic anaemia. Vitamin A deficiency is the most frequent cause of blindness in various regions of the world, most particularly in southeastern Asia and in some African countries. Vitamin A deficiency has been suggested as a causal factor of anaemia, although the mechanisms through which it produces anaemia

are not well established (Blomhoff & Smeland, 1994; Lindembaum & Allen, 1995).

In addition to the classic manifestations of deficiency of some of these vitamins, it has recently been discovered that even moderate deficiencies of some of them are associated with pathologies. For example, folic acid deficiency has been related to congenital neural tube defects (Daly *et al.* 1995). Vitamin A deficiency increases the mortality risk associated with diarrhoea and measles (West, 1991), and vitamin C deficiency has been implicated in premature rupture of the membranes during pregnancy, as well as premature birth (Casanueva *et al.* 1991, 1995). In the majority of these associations, supplementation with the relevant vitamins reduces and controls the magnitude of the problem.

Many of these vitamins play a crucial role in the prevention of chronic diseases during adult life due to their antioxidant abilities (Blumberg, 1995).

The enKid comparative study (1998–2000), which included Spain, France, Ireland, Portugal, Germany, England and the United States, demonstrated that children and adolescents are the populations at greatest risk of suffering nutritional deficiencies, in particular of Fe, vitamins C, E and B<sub>6</sub>, and folic acid. In Spain, these deficiencies are related to income level, parental education, geography, rural–urban dwelling, smoking and obesity (Serra-Majem, 2001).

### Fortification of foods is an effective, efficient and sustainable alternative to control and reduce the consequences of micronutrient deficiencies

Several decades ago, food enrichment or fortification emerged as the most efficient and sustainable option in response to the grave consequences associated with micronutrient deficiencies throughout the population. Fortification of foods massively consumed is recognized as the most efficient, safe and low-cost intervention to resolve nutrition problems (International Bank for Reconstruction and Development, 1994; Darnton-Hill, 1999).

### Definitions of the types of nutrimental additions to food

Fortified and enriched foods are products whose original composition is modified through addition of essential nutrients to satisfy the identified specific nutritional needs of defined populations (Pantanelli, 2000). In the early twentieth century, the enrichment of basic foods promoted by the industrialized nations originated a drastic reduction of illnesses, produced by micronutrient deficiencies, identified as major public health problems. In the beginning, food fortification aimed to guarantee an adequate ingestion of such nutrients throughout the population. For example, rickets was brought under control by the incorporation of vitamin D in milk, and beriberi and pellagra by the addition of thiamin and niacin to wheat and cereals. Margarine is frequently enriched with vitamins A and D to avoid a low intake in cases where margarine is used as the sole source of fat.

Recently, food fortification tends to provide additional value to some foods (Latham, 2002). Today, not only recognized nutritional substances with official dietary recommendations are added, but also other substances considered

beneficial for health (for example, omega-3 fatty acids, taurine, probiotics, etc.).

Enrichment is defined as adding supplemental amounts of nutrients already present in a food; that is, the concentration of those nutrients already present is increased. For example, the addition of thiamin, niacin or Fe to wheat flour.

Fortification is defined as the addition of nutrients not naturally present in a food or nutritional vehicle. Some examples are the addition of vitamin D to milk or fluoride to salt. Functional foods are also included in this field: they are conventional foods to which substances foreign to them are added. These substances are attributed with the ability to improve health or influence physical performance, although in many instances those benefits have not been unequivocally proven (for example, products combining vitamins A, C and E as antioxidants, energy drinks or probiotic milk products; Pantanelli, 2000).

### Examples of successful food fortification

At the global level, various basic staples such as wheat flour, salt, sugar and other condiments have been enriched with Fe, vitamin A, I, and other micronutrients, as the most cost-effective and sustainable option to eliminate micronutrient deficiencies (Salgueiro *et al.* 2002). The population of industrialized countries receives an abundant supply of vitamin A through enrichment of foods such as margarines and vegetable or canola oil. Many Central American countries, such as Guatemala or Honduras, have successful programmes enriching sugar with vitamin A (UNICEF/Micronutrient Initiative, 2004).

Salt iodization is one of the most successful enrichment programmes. Implemented in many countries since the 1970s, the salt iodization programme was adopted worldwide in 1990. Iodized salt is now available for 1.5 billion consumers throughout the world, saving millions of small children from mental retardation each year (UNICEF, 1998).

In 1996, Bolivia was the first country to achieve certification for the elimination of illnesses associated with I deficiency as a public health problem. That success was the result of several coordinated actions, i.e. legislation which transformed the political decision into a public policy, and 13 years of coordinated work between salt producers, the government and international cooperation institutions (UNICEF, 1998).

The Mexican National Nutrition Survey of 1999 revealed that 50% of infants between 12 and 24 months of age and 20% of Mexican school children suffered anaemia, most due to Fe deficiency (Villalpando *et al.* 2003).

In response to this problem, a task force including the federal government, industry and academia proposed the fortification of milk with Fe, Zn, folic acid and vitamin C under one of the oldest social programmes in Mexico (LICONSA). This milk is distributed to 5 million beneficiaries aged 6 months to 12 years. An effectiveness evaluation of the fortification strategy, carried out among 800 children between 12 and 30 months of age at the beginning of the intervention, found a 25% reduction in the prevalence of anaemia 6 months after intervention in comparison with a group treated with non-fortified milk (unpublished data).

In Chile, wheat flour fortification began in 1951 with B complex vitamins (thiamin, niacin and riboflavin, Fe, and Ca). The original vitamin pre-mix has undergone changes over time. In 1967, the Fe composite was changed to ferrous sulfate. Folic acid was added in 2000, and the possibility of adding vitamin B<sub>12</sub> has recently been considered (Hertrampf, 2003; Hertrampf and Cortes, 2004). As a result of this intervention, Chile has one of the lowest incidences of anaemia among developing countries (8% in school-aged children), comparable to that of developed countries. Nevertheless, until recently a high prevalence of anaemia still persisted among children under 5 years of age as well as in pregnant women. In an effort to reduce childhood anaemia, in 1999 ferrous sulfate and vitamin C were added to milk distributed under an existing programme (Purita milk; Olivares *et al.* 2003). One year after the programme was implemented, a decrease of 20 percentage points was observed in anaemia prevalence among this population group (28.8 v. 8.8%; Hertrampf, 2003; Torrejón *et al.* 2004).

During the economic crisis of 1983 in Venezuela, the low-income population (approximately 80% of Venezuelans) reduced its consumption of nutritious foods, which was reflected in an increased prevalence of Fe deficiency. In response, in 1993 the Venezuelan Government through the Special Commission on Enriched Foods initiated a fortification programme of wheat and cornflour with ferrous fumarate. Also thiamin, riboflavin and niacin were added.

Both cereals represent 45% of total energy consumption among the Venezuelan population. In school-aged children and adolescents, the fortification of these flours resulted in a reduction in the prevalence of IDA from 37 and 19% respectively in 1992, to 15 and 10% in 1994 (García-Casal and Layrisse, 2002).

### Recommendations for successful food fortification programmes

Many of the fortification programmes proved successful; however, the practicalities of the enrichment process are complex. They demand that government and industry act together. Recent experience indicates that enrichment is successful when the food manufacturers participate from the beginning in the production of norms and in the solution of technical and market problems. Those are the foundations of the programme's success or failure. All actors must contribute in a coordinated way to the success of the programme, ranging from the producers to the consumer, on whose state of nutrition the programme will have an effect (Maberly, 2003).

Additional considerations are the type of fortifier to be added, its bioavailability, and the adequate balance between substances that inhibit or facilitate absorption. Adequate vehicles for food fortification must also be identified. They must be consumed extensively by the population and of reasonable price. For example, staples like wheat, corn or rice, sauces and condiments offer important advantages as fortification vehicles (Thuy *et al.* 2003) given that they form part of the habitual diet in many countries. For example, fortified soy or fish sauce has proven to be an excellent food fortification vehicle in Vietnam.

Evaluation of the impact of food fortification on the target population is necessary for feedback and in some cases for re-engineering the formulation or the programme as a whole.

The effectiveness and efficiency of fortified foods relies largely on negotiations between researchers, politicians, producers and consumers. A multisector effort is required linking relevant government organizations, public health organizations, academia, producers, food distributors and even consumers, towards the common goal to improve the population's nutritional state.

Occasionally fortification may have positive and negative commercial consequences. Manufacturers will appreciate the recognition of their efforts, allowing reasonable claims that may help in achieving their marketing aims. In other cases changes in the sensorial characteristics of a product (taste, appearance or smell) may negatively affect sales and market participation; those should be carefully tested and avoided. One case that exemplifies this occurred in Venezuela in the late 1980s, when cornflour was enriched with ferrous fumarate. Instead of its usual white colour, the flour was grey in the market trials. Fearing that consumers would reject the product, flour manufacturers resisted fortification. The situation was solved in 1992 when the Venezuelan National Institute of Nutrition recommended that the flour be enriched with a mixture of Fe compounds that did not alter the colour of the flour (Layrisse *et al.* 1996).

In 1974, in Guatemala, the enrichment of sugar with vitamin A was approved by law. The fortification programme quickly fell apart because the producers were not convinced of its effectiveness and the necessary foreign currency to buy the vitamin was unavailable. As a result, the law was not enforced. The programme was rescued 10 years later when the Nutrition Institute of Central America and Panama and UNICEF, explaining the relevance of enrichment, provided technical assistance to manufacturers and helped them obtain vitamin A at below-market prices and through donations.

The Panamanian Health Ministry currently enforces similar laws: when sugar with low levels of vitamin A is found in random testing, the manufacturer first receives a warning and if the manufacturer continues to fail to comply, receives either a fine or closure of their business (UNICEF, 1998).

It is essential to monitor the entire process to guarantee that enriched products reach quality norms. In Chile, Fe enrichment of wheat flour began in the early 1950s. However, quality monitoring and supervision did not begin until 1967, and evaluation of the effectiveness of the programme until 1975, when the first national survey of Fe status among the population was undertaken (Hertrampf, 2003).

In addition, it is strongly recommended that enrichment be mandatory. In addition the manufacturers should be convinced of the benefits of enrichment, in order to assure an equal burden among all individual factories, and to eliminate any possible resistance.

In addition to the nutritional value achieved by food fortification, it offers several advantages: it does not alter the taste and smell of the food; it does not require people to change their eating habits or be convinced of the need to consume a particular product; there is little risk of excess consumption because the added micronutrient has been calculated in accordance with its requirements and dietary recommendations; the final cost of fortification is usually very low and when transferred to the

consumer it does not impact on the price; and finally, it is more efficacious than any other nutritional intervention.

### General observations

Fortification of foods is a convenient population strategy to reduce and control micronutrient deficiencies especially in regions of the world where available foods cannot fulfil the intake requirements of the population. Fortification should, therefore, be considered as one policy to combat micronutrient deficiencies.

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