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Food fortification

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Introduction

Food fortification (FF) is defined as the addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups [1]. Fortification therefore differs from enrichment, which is the process of restoring the nutrients to a food removed during refinement or production. Fortification commonly uses staple foods as vehicles to deliver micronutrients generally lacking or not contained in sufficient concentration in the diet of a population and has been practiced since the 1930s to target specific health conditions such as iodine deficiency through the iodisation of salt, anaemia through the fortification of cereals with iron and vitamins, and neural tube defects through the fortification of wheat flour with folic acid.

Food fortification includes biofortification, microbial biofortification and synthetic biology; commercial and industrial fortification, and home fortification. The several types of FF are distinct because different techniques and procedures are used to fortify the target foods. Biofortification involves creating micronutrient-dense staple crops using traditional breeding techniques and/or biotechnology. Using biotechnology (genetic engineering) to biofortify staple crops is more modern and has gained much attention in recent years. The most popular example of this approach is the transgenic 'Golden Rice' containing twice the normal levels of iron and significant amounts of beta-carotene [2]. Microbial biofortification involves using probiotic bacteria (mostly lactic acid bacteria), which ferment to produce β-carotene either in the foods we eat or directly in the human intestine [3]. Commercial and industrial fortification involves fortifying commercially available products such as flour, rice, cooking oils, sauces, butter etc. with micronutrients and the process occurs during manufacturing. Home fortification consists of supplying deficient populations with micronutrients in packages or tablets that can be added when cooking/consuming meals at home (basically a merger of supplements and fortification).

Fortification strategy to reduce micronutrient deficiency

Food fortification has lowered the incidence of micronutrient deficiencies (MNDs) that were previously common, and has, improved the health status (and also other key indicators, such as economic and educational status) of a large proportion of the population(s) involved [4]. In 2002 the World Health Report identified iodine, iron, vitamin A and zinc deficiencies as being among the world's most serious health risk factors [5]. The four key strategies identified to address MNDs are: dietary improvement, supplementation, FF and global public health and other disease control measures. FF is recognized as one of the most cost effective methods. Short-term strategies such as nutrient supplementation (giving a large dose of the micronutrient as a medicinal supplement) have been effective in providing immediate relief in several countries, but this approach was not sustainable in the long term [6]. The World Bank, WHO, UNICEF, Micronutrient Initiative (MI) and Global Alliance for Improved Nutrition (GAIN) also have identified fortification, as among the most cost-effective of all health interventions [4] and fortification of staple foods with micronutrients is the strategy gaining momentum currently in many developing countries [4].

Complementary feeding with fortified food products

While fortified complementary foods are widely used in industrialised countries, they are beyond the reach of the poor in developing countries. The challenge is to increase the density of complementary foods with multiple fortifications of essential micronutrients at affordable prices. Three types of fortified products (precooked or instant) have been developed for infants and young children: fortified blended foods (FBF), complementary food supplements (CFS), and micronutrient powders (MNP). FBFs and CFSs have been formulated to be prepared as semisolids or solids (not liquids) that can replace traditional porridges so that they are less likely to interfere with breastfeeding and complying with local and international regulations, including the International Code on Marketing of Breast-Milk Substitutes and many relevant Codex Alimentarius standards, including hygiene, additives, forms of added micronutrients, and protein quality [7, 8]. The MNPs have been developed to be used as "point-of-use fortificants" or "home fortificants" [9]. Feasibility of iron sprinkles as a point-of-use fortificant on homemade complementary foods has shown to increase absorption of iron [10]. Some other types of fortified complementary foods, such as cookies or biscuits and compressed bars, also have been used in emergency feeding programmes for young children.

Food fortification in developed countries

The expanding range of fortified foods has been justified by the fact that recommended dietary allowances for many nutrients are commonly not met through the normal diet. While FF continues to be widely used, the regulation of fortification is currently receiving more attention than the technologies involved because there is a legitimate fear of over-fortification as manufacturers seek to use fortification as a marketing tool. However, the virtual elimination of micronutrient deficiencies in developed countries has been attributed in large part to fortification [6]. Although it is well recognised that FF is one of the preferred and cost-effective approaches in combating micronutrient malnutrition, its effectiveness in developing countries is yet to be demonstrated. One of the limiting factors is the lack of simple and affordable technology to fortify foods with stable and bioavailable nutrients without compromising commonly accepted taste and appearance [3].

Food fortification in less developed countries

In south East Asia, progress has been made in reducing iodine deficiency through salt iodisation. In central American countries, fortification of sugar with vitamin A demonstrated an improvement in vitamin A status of the population. In the past two decades, flour fortification with iron has been implemented in Chile and Venezuela, resulting in an improvement in the iron status of the population. Asian societies are predominantly rice eating and the technologies to fortify rice are limited. With rising consumption of wheat flour in Asia, many countries such as India, Indonesia and the Philippines initiated programmes for fortification of flour with iron, vitamin A, folic acid and other B vitamins. In Sri Lanka, fortification of wheat flour was experimented but a positive effect was not found. In Thailand, other foods like noodles and fish sauce are fortified with micro-nutrients. Yet, vast populations in the region still remain affected by MND. However, as opposed to the developed ones different considerations are involved in the establishment of FF programmes such as, identification of the need for nutritional intervention, determine required levels of fortification, selection of appropriate carrier and fortificants, determination of technologies to use in the fortification process and lastly the determination of some mechanism to assess whether the nutritional objectives of the programme are being met.

General principles of FF and quality control

A technical consultation on FF convened by the FAO in 1995 focused on technology and quality control, and in addition, the Codex Alimentarius Commission (1995) has adopted the general principles for the addition of essential nutrients to Foods [6]. Although these general principles of FF are recognised internationally, incorporating them into domestic law requires a clear understanding of the nutrition problem involved [3, 5]. While its effectiveness is not in doubt, FF needs to be controlled by appropriate legislation. Adherence to legislation will ensure that the objectives of a food-fortification programme are achieved and that the levels of micronutrients are controlled within safe and acceptable limits.

Problem identification

In order to successfully develop and implement a FF programme, a country needs to have a clear understanding of the nature of the nutrition problem (5) by collecting information on extent and severity of the problem, whether it affects different demographic groups, implications, commitment of government and producers for addressing the problem, major causes and resources available.

Bioavailability of fortificants

Absorption of added nutrients, particularly iron and zinc, varies widely depending on the fortificant used. The nature of the food vehicle, and/or the fortificant, may limit the amount of fortificant that can be successfully added. Selection of the form of micronutrient to be used as a fortifying agent requires consideration of the bio-availability, chemical and physical properties of both the fortifying agent and the food to be fortified [6].

Benefits and experience in rice fortification on micronutrient status

Decades of research on rice enrichment and forti-fication practices have provided a better understanding of the technology needed; however, functionally suitable and bioavailable iron fortificants have to be developed and attention needs to be directed to improving stability of added nutrients [11]. The appearance, texture, taste, and aroma of enriched rice must be evaluated to assess consumer acceptability and coating mixtures containing micronutrients have been developed for rice fortification [12]. Fortifying flour is much simpler because the nutrients that are available in powdered form can simply be mixed into the flour. We have reported that fortification of rice flour with iron, zinc and folate increased the absorption of iron and zinc in preschool children, in addition to the improvements shown in their growth and micronutrient status [13]. The sensory evaluation carried out by us revealed that the acceptability of fortified rice flour was high. As such, rice flour was recommended as a suitable vehicle for fortification.

Table 1. Different types of food fortifications – pros and cons

		Economic	*Environmental*	*Ethical*	*Legal*	*Social*	*Others*
Industrial fortification	Pros	Can be made available at a low cost, restores the micronutrients lost in processing/cooking	Does not interfere with the natural state of plant or animal species			large populations do have the ability to purchase commercial foods	
	Cons	Producers may increase the price		May be viewed as unethical to place substances in people's food without their consent	Producers of the commercial goods must agree to the terms of fortification	People who can't afford commercial foods won't benefit, may not reach all segments of the population	some people are too far from markets to purchase commercial products
Home fortification	Pros	Can be distributed as widely and cheaply	Not disturbing the natural state of plant or animal species	The approach is not forced on any person, it is their choice to utilize the additives		Encourages self-reliance People's behavior patterns are not effected	
	Cons	Not a sustained approach as the supply of additives must be replenished by a producer outside	No changes made in the normal food intake	People may feel uncomfortable adding a substance to their food without knowing what it is		No guarantee the targeted population will participate	Requires education programme
Bio fortification (Genetically Modified)	Pros	Once introduced, highly sustainable and require minimal intervention	Trace mineral can help plants resist disease and environmental stressors			Large population benefited	Well suited approach since it utilizes the fact that the daily diet of low income micronutrient deficient populations, is large quantities of staple foods
	Cons		Lack of knowledge on the impact on local eco systems Mono cultures may reduce biodiversity	Many may believe that nature shouldn't be altered	Regulation and quality control strictly needed	Farmers and consumers may not accept sensory changes of biofortified crops	

Advantages and limitations of food fortification

Being a food based approach FF has several advantages over other interventions as it does not necessitate a change in dietary patterns of the population, can deliver a significant proportion of the recommended dietary allowances for a number of micronutrients on a continuous basis, and does not call for individual compliance. It could often be dovetailed into the existing food production and distribution system, and therefore, can be sustained over a long period of time.

If consumed on a regular and frequent basis, fortified foods will maintain body stores of nutrients more efficiently and more effectively than will intermittent supplements. Fortified foods are also better at lowering the risk of the multiple deficiencies, an important advantage to growing children who need a sustained supply of micronutrients for growth and development, and to women of fertile age who need to enter periods of pregnancy and lactation with adequate nutrient stores.

The limitations of FF are also well known: FF alone cannot correct micronutrient deficiencies when large numbers of the targeted population, either because of poverty or locality, have little or no access to the fortified food, when the level of micronutrient deficiency is too severe, or when the concurrent presence of infections increases the metabolic demand for micronutrients. In addition, various safety, technological and cost considerations can also place constraints on FF interventions. Thus proper FF programme planning not only requires assessment of its potential impact on the nutritional status of the population but also of its feasibility in a given context. Further, it needs to be controlled by appropriate legislation [5]. Table 1 further illustrates the pros and cons of different types of FF programmes that can be implemented.

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