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Mineral fortification and supplementation

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Abstract
Fortification is the process of adding nutrients or non-nutrient bioactive components to edible products (e.g., food, food constituents, or supplements). Fortification can be used to correct or prevent widespread nutrient intake shortfalls and associated deficiencies, to balance the total nutrient profile of a diet, to restore nutrients lost in processing, or to appeal to consumers looking to supplement their diet. Food fortification could be considered as a public health strategy to enhance nutrient intakes of a population. Food fortification is one of the most cost-effective nutrition interventions to tackle Hidden Hunger on a large scale. In high-income countries, food fortification has been in place for almost a century, and has successfully eliminated deficiency diseases such as rickets and pellagra.

Keywords: food fortification, supplements

Introduction
The World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) have identified four main strategies for improving micronutrient malnutrition:

1. Nutrition education leading to diets that are more diverse and better quality
2. Food fortification and biofortification
3. Supplementation
4. Disease control measures

Each of these strategies has a place in eliminating micronutrient malnutrition. To achieve maximum impact, the appropriate mix of these strategies should be in place simultaneously to promote consumption and utilisation of an adequate diet for all people in the world (WHO/FAO, 2006) [1]. Food fortification is considered a sustainable public health strategy because it can reach wider at-risk populations through existing food delivery systems without requiring major changes in existing consumption patterns. Compared to other interventions, food fortification is likely to be more cost-effective, and – if fortified foods are regularly consumed – it has the advantage of maintaining steady body stores.
In 2006, the WHO published evidence-informed guidelines for various aspects of fortification. These guidelines included the appropriate selection of vehicles and fortificants; how to determine fortification levels; and the implementation of effective and sustainable food fortification programmes.
Fortification, which was initially limited to a few select foods, now includes a range of grain products, snack foods, meal replacements, artificial sweeteners, and even bottled water. In addition to the consumption of fortified foods, intake of multivitamin and mineral supplements and individual nutrient supplements is on the rise. In this paper, we examine the health benefits and consequences of vitamin and mineral excess (from supplements and fortified foods) in the general U.S. population, using the intake of folic acid, calcium and vitamin D to illustrate the pros and cons of this issue, and highlight concerns that regulatory agencies should address issues related to overconsumption of nutrients via food-fortification and supplements..

Supplementation: Supplementation refers to the provision of added nutrients in pharmaceutical form (such as capsules, tablets, or syrups) rather than in food where it is most appropriate for targeted populations with a high risk of deficiency or under special circumstances, such as during pregnancy or in an acute food shortage (Ottaway PB, 2008). Globally, supplementation with iron tablets is the most widely used strategy for the prevention and control of iron-deficiency or anemia in pregnancy. Pregnant women require nearly three times as much iron as nonpregnant women owing to the physiological demands of pregnancy (expanded red-blood-cell volume, the needs of the fetus and placenta, and blood loss at delivery).

This high requirement is unattainable by most pregnant women in developing countries and therefore, iron supplementation is recommended during pregnancy on daily or weekly basis (Untoro J, 2002). Iron supplementation is also found to effectively treat severe and moderate anemia in pre-school children (Hettiarachchi M, 2008).
Supplementation programmes are used as a short-term intervention measures. It has advantages of rapid coverage of a high-risk population by providing direct a controlled and concentrated dose of the micronutrient to the target group. In addition, supplementation has an immediate impact on micronutrient status and associated functional outcome. Most supplementation programs have been shown to be cost-effective in achieving their nutritional goals and health impacts. However, inadequate coverage (where deficient individuals are missed or reached irregularly), inability to sustain high coverage over long periods of time as financial, political, or other health priorities change, and poor compliance by target individuals (e.g., iron supplementation during pregnancy) hamper the long term goals. As a result, supplementation is mostly replaced with long-term, sustainable food based measures such as fortification and dietary modification, usually by increasing food diversity (Caballero B, Allen L, Prentice A, 2005).

Food fortification: The approach here is to fortify food with essential nutrients. The United Nations' Food and Agriculture Organization recommends that governments in countries with high malnutrition rates consider fortifying food with iodine, iron and vitamin A in particular and that they regulate fortification. The UN's Codex Alimentarius Commission lays down international food standards, which list the basic conditions for national fortification programmes: (1) direct evidence of an appropriate rate of malnutrition; (2) identification of a food carrier (such as flour or edible oil) that is consumed by the whole of the malnourished population and whose consumption is recorded; and (3) an evidence base for minimum and maximum fortification rates.
Food fortification is attractive because it does not require the target groups to change their diet but can be implemented by the food industry and because it reaches large numbers of consumers through retail. It is a particularly effective way of tackling deficiencies in densely populated urban areas. Mandatory labelling tells consumers that the food they are buying has been fortified, while accompanying 'social marketing campaigns' are often effective. As well as reliable data on malnutrition rates, national programmes need to be able to test the micronutrient content of food, which requires reliable laboratory testing and rapid mobile testing in the field

Dietary diversification
Linking cultivation of a variety of staple foods with a high vitamin and mineral content to nutritional education can produce better consumer behaviour, Having a balanced diet involves a number of factors and is a long-term objective, especially by contrast with dietary supplementation.
Diversification can take the form of improved agricultural production, development of vegetable plots, a good variety of foodstuffs and sound preparation methods within families, or multi-sector nutritional advice and training in schools. It can also be delivered through health services, along with food supplementation and fortification and can play a major part in helping to reduce malnutrition. The approach here is to fortify food with essential nutrients.
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Fortification / Enrichment
Food fortification or enrichment is the process of adding micronutrients (essential trace elements and vitamins) to food. Sometimes it's a purely commercial choice to provide extra nutrients in a food, while other times it is a public health policy which aims to reduce the number of people with dietary deficiencies within a population. Staple foods of a region can lack particular nutrients due to the soil of the region or from inherent inadequacy of a normal diet. Addition of micronutrients to staples and condiments can prevent large-scale deficiency diseases in these cases.
As defined by the World Health Organization (WHO) and the Food and Agricultural Organization of the United Nations (FAO), fortification refers to "the practice of deliberately increasing the content of an essential micronutrient, i.e. vitamins and minerals (including trace elements) in a food irrespective of whether the nutrients were originally in the food before processing or not, so as to improve the nutritional quality of the food supply and to provide a public health benefit with minimal risk to health", whereas enrichment is defined as "synonymous with fortification and refers to the addition of micronutrients to a food which are lost during processing"

Large-scale fortification of staple foods
Wheat flour
Since wheat flour is the primary staple food in a large number of countries in Europe, North America, the Middle East and North Africa, and since consumption is increasing with the globalisation of diets, it is by far the most commonly used food vehicle in large-scale staple fortification programmes. There are now 85 countries (plus the Indian province of Punjab) with legislation to fortify wheat flour produced in industrial mills. All the countries with mandatory legislation fortify wheat flour with iron and folic acid except Australia which does not include iron, and Congo, Nigeria, Philippines, UK and Venezuela, which do not include folic acid. Five countries (Democratic Republic of Congo, Gambia, Namibia, Qatar, and United Arab Emirates) fortify at least half their industrially milled wheat flour through voluntary efforts. Mandatory fortification of wheat flour has been reported as a key success in Morocco and Uzbekistan, with the latter having wheat flour enriched with iron and folic acid in half of the nation's flour mills (Wirth JP et.al 2012). In 2009, Kyrgyzstan introduced the law "On the Enrichment of Bread Flour" envisioning a phased transition of all mills to mandatory production of enriched flour.

Maize
More than 200 million people rely on maize as a staple food, especially in sub-Saharan Africa, Southeast Asia, and Latin America. Estimates suggest that maize provides approximately 20% of the dietary energy (calories) consumed in the world (Pasricha SR *et al*. 2012) [8]

Sixteen countries have maize fortification programmes in place. Mandatory maize flour fortification is happening in Brazil, Costa Rica, el Salvador, Kenya, Mexico, Namibia, Nigeria, Rwanda, South Africa, Tanzania, Uganda, the United States and Venezuela while Ghana, Malawi, and Mauritania have voluntary fortification. Although it is estimated that 48% of industrially milled maize flour is currently fortified, one of the main challenges is that many people largely consume locally produced, unprocessed (and unfortified) maize meal milled at the village level or in small-scale hammer mills. Consequently, the number of small mills without fortification technology in a country will affect whether the fortification of maize flour is a feasible option (Pena-Rosas JP, 2014) [10].

Rice

Of the 222 million metric tons of rice that is industrially milled each year, less than 1% is fortified with essential vitamins and minerals. Currently six countries (Costa Rica, Nicaragua, Panama, Papua New Guinea, the Philippines and the USA) have mandatory rice fortification, and Brazil, Colombia and the Dominican Republic have large-scale non-mandatory rice fortification programmes. While this might be "considered an untapped opportunity for food fortification", it has been a considerable technical challenge to fortify rice successfully, although attempts have been made for at least 30 years. Japan has a decades-long history of adding fortified grains to rice before cooking, with fortified rice being available on the market since 1981, but there has not been much interest elsewhere. Unlike other fortified food staples (such as maize or wheat), the rice grain must be directly fortified; it is not enough to fortify the sub products (e.g. flour or porridge). The main approaches to rice fortification have been to either cover rice grains with a micronutrient-rice adhesive mixture by dusting, coating or extrusion, or to add micronutrients to rice granules made up of rice flour to be indistinguishable from other grains (Steiger G, Muller-Fischer N 2014) [11]. For example, Ultra Rice® uses formulated rice grain analogues of microencapsulated iron pyrophosphate and other micronutrients (including thiamine, zinc, vitamin A, folic acid, and other B vitamins) mixed with rice flour. When these grains are blended with traditional rice (typically at a ratio of 1 to 100), the resulting fortified rice is nearly identical to unfortified rice in aroma, taste, and texture.

The efficacy of rice fortification has been demonstrated. An efficacy study of fortified rice in Mexico in nonpregnant, non-lactating women between the ages of 18 and 49 found that the average iron fortificant ingested was 13mg/day. Compared to the control group, the mean plasma ferritin concentration and estimated body iron stores were significantly higher, and transferrin receptors were lower. The mean haemoglobin concentration was significantly increased only in those women with baseline haemoglobin <12.8g/dl and the overall prevalence of anaemia were reduced by 80%. Studies in the Philippines of school-aged children with iron-fortified rice have also been found to demonstrate efficacy (Angeles *et al*. 2008)

Large-scale fortification of condiments and Salt

Salt

Universal iodisation of salt is the preferred strategy to control Iodine Deficiency Disorders (IDD) in most countries. Salt is the vehicle of choice for fortification as it is consumed by nearly everyone at roughly equal amounts throughout the year and is inexpensive (less than 0.02-$0.10 USD per person, per year). Salt production is often limited to a few centres, which facilitates quality control and the addition of potassium iodate or potassium iodide does not affect the taste or smell of the salt (**Zimmermann MB, Jooste PL, Pandav CS 2008) [13].** Iodine deficiency has been considerably reduced due to iodisation of salt; this is now recognised as one of the great public health nutrition achievements. Whereas in 1993, there were 110 countries in the world with iodine deficiencies, there are now only 25 countries deficient in this nutrient. Nevertheless, although there is recognition of the importance of salt iodisation, some 30% of LMIC households are still not consuming iodised salt at home. There is especially low coverage in some European and Central European countries, in South Asia, and in some sub-Saharan African countries. At the same time, there is increasing recognition that as salt consumption patterns change, the promotion of the use of iodised salt in processed foods and condiments (such as bouillon) is an important focus of Universal Salt Iodisation (USI) programmes. Iodine intakes in other industrialised countries, including Australia, parts of Europe and the USA, have fallen in recent years. Mild iodine deficiency has reappeared in these areas due to declining iodine residues in milk products, changing salt consumption patterns due to concerns about hypertension; culinary choices, or consumer decisions to not purchase iodised salt; and a decrease of use in manufacturing and processing of foods. The fortification of other food vehicles with iodine has also been suggested and tested. There have been attempts to introduce double-fortified salt (iodine and iron) and even triple-fortified with vitamin A. While technically feasible, this approach has not gained traction as a public health measure in part because it requires such a high degree of salt purity.

Condiments

Increasingly, condiments, spices and seasonings are being used as vehicles to increase the intake of vitamins and minerals (WHO 2015) [15]. Fortification of condiments or seasonings has the potential to improve micronutrient intake in many populations, especially as they tend to be consumed consistently by most of the targeted population, as is the case in many Asian and African countries. Mandatory or market-driven condiment fortification with iron has been used with various vehicles: soy sauce, fish sauce, salt, and bouillon cubes (WHO 2006) [1]. At least one systematic review has demonstrated that iron fortification of condiments is associated with increased hemoglobin, improved iron status, and reduced anaemia across targeted populations. Until now, most of the research on fortification of condiments and seasonings has been on NaFeEDTA added to soy and fish sauces in Southeast Asian countries, as well as various micronutrients being added to salt in other countries. Other condiments (such as bouillon cubes and curry powder) are now also being fortified with iron and other vitamins and minerals.

Conclusions

Fortification and micronutrient supplementation for the most vulnerable is proven to avert much of the morbidity and mortality associated to micronutrient malnutrition. Micronutrient deficiency often goes unnoticed within the societies which are otherwise healthy. Food fortification is one of the most cost-effective nutrition interventions to tackle Hidden Hunger on a large scale. In high-income countries, food fortification has been in place for almost a century, and has successfully eliminated deficiency diseases such as rickets and pellagra. The purpose of the Future Fortified Global

Summit on Food Fortification held in Arusha in 2015 was to develop a vision and strategy for fortification that would contribute to the Sustainable Development Goals and beyond. The summit issued an "Arusha Statement on Food Fortification", which included commitments to address remaining challenges around monitoring and compliance, equity and small-scale milling.

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