State of the World Report 2015:

FOOD FORTIFICATION

SYNOPSIS REPORT

Micronutrient FORUM

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Acknowledgements

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1. Introduction

Micronutrient deficiencies – and the negative consequences of a diet lacking in essential vitamins and minerals/trace elements – continue to pose significant public health problems for many low- and middle-income country (LMIC) populations. This hidden hunger is more prevalent in vulnerable populations, including women of reproductive age and young children (1), and female adolescents (2).

It is estimated that at least 1.6 billion people around the world suffer from anaemia (3). Globally approximately 2 billion suffer from chronic micronutrient deficiencies (4), with the most common forms of micronutrient malnutrition being caused by a lack of iron, folate, iodine, vitamin A, and zinc (see Figure 1).

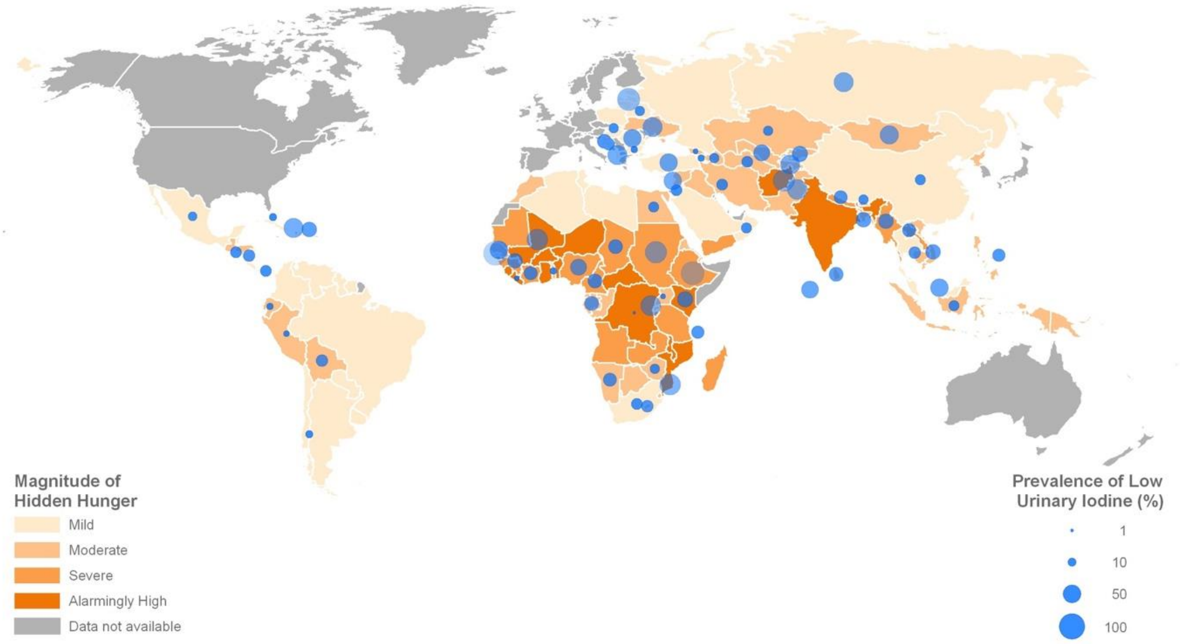

Figure 1. Magnitude of prevalence of micronutrient deficiencies worldwide (4)
(Note: Prevalence of low urinary iodine is based on a single spot urine sample.)

Overall, micronutrient malnutrition has significant health and economic consequences (5-8). Micronutrient deficiencies alone have been estimated to cost an annual GDP loss of 2% - 5% in low and middle-income countries (LMIC) [23-25], with direct costs estimated between US$20 to $30 billion every year [24]. Consider anaemia, which is estimated to cause a 17% reduction in productivity in heavy manual labour, as well as an estimated 2.5% loss of earnings due to lower cognitive skills [23].

Annually, 40-60% of children 6-24 months of age in LMIC are at risk of impaired cognitive development due to iron deficiency, while anaemia during pregnancy contributes to 20% of all maternal deaths, and reduced work productivity in adults (8). Iodine deficiency causes some 35 million newborns to be born intellectually impaired (9) as a result of poor maternal iodine status. The estimated intellectual losses for these newborns range from 7.4 [19] to 15 IQ points [20].

Insufficient intake of vitamin A results in an estimated 250,000 to 500,000 cases of childhood blindness every year. An estimated 250 million preschool children are vitamin A deficient (8), leading to a compromised immune system and increased mortality risk. In 2013, it was estimated that, annually, 2.3% and 1.7% of all childhood deaths can be attributed to deficiencies in vitamin A and zinc (8). Approximately 300,000 children are born each year with severe birth defects due to maternal folate deficiency [22].

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:

- Nutrition education leading to diets that are more diverse and better quality
- Food fortification and biofortification
- Supplementation
- Disease control measures (10)

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 (10).

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 (11). 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 (10).

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(10). Today, 10 years after the WHO guidelines were published, this report will provide an objective overview of the state of large-scale food fortification in the world, with particular emphasis on the fortification of staple foods. Typically, the fortification of staple foods is mandatory, but voluntary programmes are included where appropriate. The report will describe essential components of successful fortification programmes and describe remaining technical challenges and barriers. This will inform how to prioritise recommendations and next steps, which will be discussed and conclusions drawn. The report focuses on mass fortification and does not address home fortification, biofortification or specialised fortified foods for specific target groups (for example, fortified complementary foods for infants and young children who typically cannot consume enough of fortified family foods to match their dietary requirements (12)). An initial expanded version of this report was presented at the #FutureFortified Global Summit on Food Fortification, which took place in Arusha, Tanzania in September, 2015. This synopsis report summarises the initial version and includes some of the recommendations from the summit, which have been described in detail in other publications (13).

2. Cost-effectiveness, efficacy and safety of food fortification

Efficacy and effectiveness

The efficacy of food fortification has been demonstrated consistently and is now generally accepted (7, 10). Recent systematic reviews suggest that micronutrient fortification of foods has the potential to significantly increase serum micronutrient concentrations and reduce deficiencies (11, 14). For instance, a recent systematic review of randomised and pseudo-randomised controlled trials included 60 acceptable trials on iron fortification and iron biofortification. This review found that iron fortification of foods resulted in a significant increase in haemoglobin (0.42g/dL 95% CI 0.28-0.56) and serum ferritin (1.36 ug/L; 95%CI 1.23-

1.52), and a reduced risk of anaemia (RR: 0.59; 95%CI:0.48-0.71) and iron deficiency (RR: 0.48; 95%CI: 0.38-0.62) (15). However, no effect was found on zinc concentrations, rate of infections, physical growth or mental and motor development (15). Vitamin A fortification efficacy has been established in the Philippines with fortified monosodium glutamate (16), margarine (17), and wheat buns (18) trials (10). The efficacy of multiple micronutrient fortification has been demonstrated in several studies in Botswana, South Africa and Tanzania (cited in (10)).

The effectiveness of fortification programmes is not only determined by the efficacy of the fortified food but also by effective implementation, monitoring, quality control and compliance and correction of identified issues. Starting in the early 20th century in the Americas and Europe, food fortification has made significant contributions to the elimination of deficiency diseases. This has usually occurred when concurrent social changes and changes in the public health environment were in place to improve diets. For instance, marked declines in the prevalence of beriberi from thiamine deficiency have been observed in the southern US and Canada after voluntary and mandatory fortification of flours and bread with high-vitamin yeast (5, 19). The mandatory addition of vitamin D to milk, which started in 1965 in Canada, has eliminated the widespread problem with childhood rickets (19). Salt iodisation, in place since the 1920s in Switzerland and the USA, has reduced goitre prevalence globally and Universal Salt Iodisation has led to the prevention of as many as 750 million cases of goitre in the past twenty five years (Gorstein J, personal communication). After the introduction of vitamin-A fortified margarine in Denmark in 1917, the number of cases of xerophthalmia reported at Copenhagen Hospital fell by more than 90% and had been eliminated by 1918 (20, 21). A recent systematic evaluation of 76 studies and 41 contextual reports (13) concluded that there is strong evidence of important and measurable improvements in micronutrient status and health outcomes in women and children after food fortification in wide geographic settings in LMIC. Fortifying with vitamin A was estimated to reduce the prevalence of deficiency in children under five from 33.3% to 25.7% globally. Effectively fortifying with iron would reduce anaemia by 14%. Salt iodisation has reduced goitre by 40% in countries such as Pakistan, and fortifying flour with folic acid has reduced NTDs by 40-50%.

Safety

Ensuring safety requires that all partners – from industry to consumers - do their part in the fortification system. Ultimately, it is the responsibility of governments. Effective safety practices require the enforcement of legislation and regulations, as well as active and rigorous compliance to established standards. The possibility of overconsumption of nutrients in groups outside the target population, (and monitoring additional intakes and nutritional status associated with the consumption of fortified foods) should be actively and consistently monitored as an integral part of any fortification programme (22). In China, careful monitoring has identified counties where much of the population is likely getting too much iodine from the local water source as judged by urinary iodine levels. To address this issue, iodine is being reduced in the iodised salt that is distributed in these areas (23). Using modelling techniques for fortificants, one study concluded that the adoption of fortification content for staple foods near the safe limit also brings into consideration the need to restrict the voluntary addition of the specific nutrient to other foods and to dietary supplements (24), especially where risk of deficiency is not universal (25).

Cost-effectiveness

Although the cost-benefit ratio of fortification depends on local conditions and deficiency trends, resources, food vehicles and fortificants used, food fortification is generally recognised as one of the most cost-effective interventions. In a review presented at the #FutureFortified summit, Horton et al. (13) estimated that the an benefit:cost ratio (BCR) of iron fortification in 10 countries with high levels of anaemia is 8.7:1. For iodisation of salt, a BCR of around 70:1 (26) is demonstrated, while for folic acid a range extended from 11.8:1 for Chile to 30:1 in South Africa. The cost-effectiveness of staple foods with vitamin A was estimated at US$81/DALY. Overall, after a thorough review of costs and benefits, the Copenhagen Consensus proposed micronutrient fortification – particularly iron fortification of staples and salt iodisation – to be of the "best-buys" among the 30 interventions they considered for addressing the 10 great challenges facing global development (6). For an annual cost of $286 million US, they estimated the corresponding benefits would be $2.7billion(a BCR of 9.5:1) (6).

3. Overview of food fortification programmes

As estimated by the Food Fortification Initiative (FFI), 30% of the world's industrially milled wheat flour, 48% of the industrially milled maize flour, and 1% of industrially milled rice is now being fortified with at least iron or folic acid, through both mandatory and voluntary initiatives. A total of 86 countries have mandatory programmes for cereals (see Figure 2).

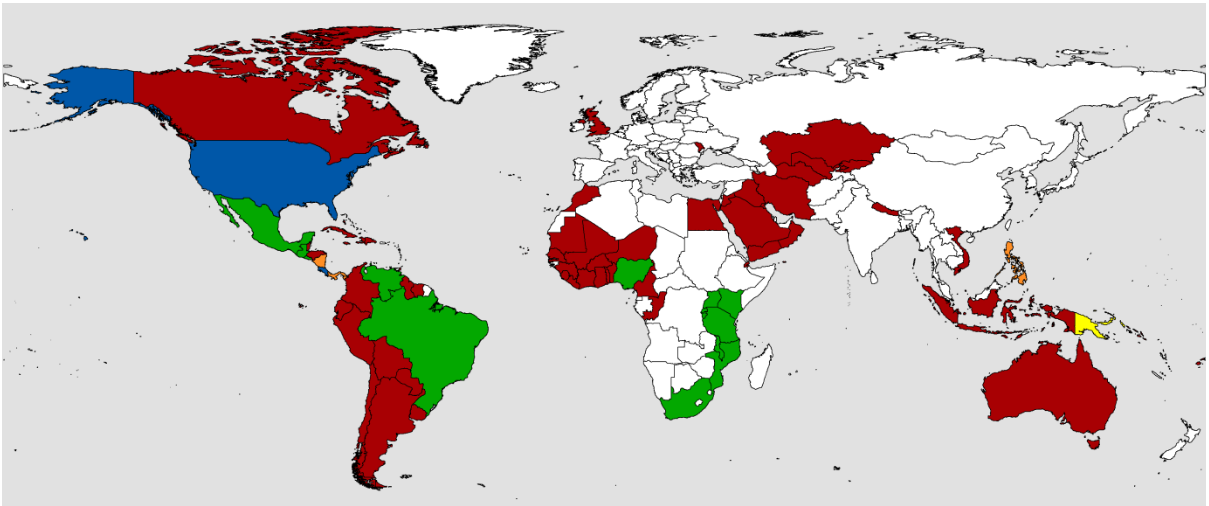

Figure 2. Countries with mandatory cereal grain fortification. Red countries have mandatory legislation for wheat flour, green countries for wheat and maize, orange for wheat and rice, blue for wheat, maize and rice, yellow for rice.
(Source: Food Fortification Initiative. http://www.ffinetwork.org/global_progress.php).

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 (see Figure 3). 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 (27). 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 (27). 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 (28). In Egypt's national wheat flour fortification programme, ferrous sulphate and folic acid are added to all wheat flour produced under the national food subsidy programme for baladi bread. This traditional bread reaches an estimated 50 million Egyptians on a daily basis (29). 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 (30).

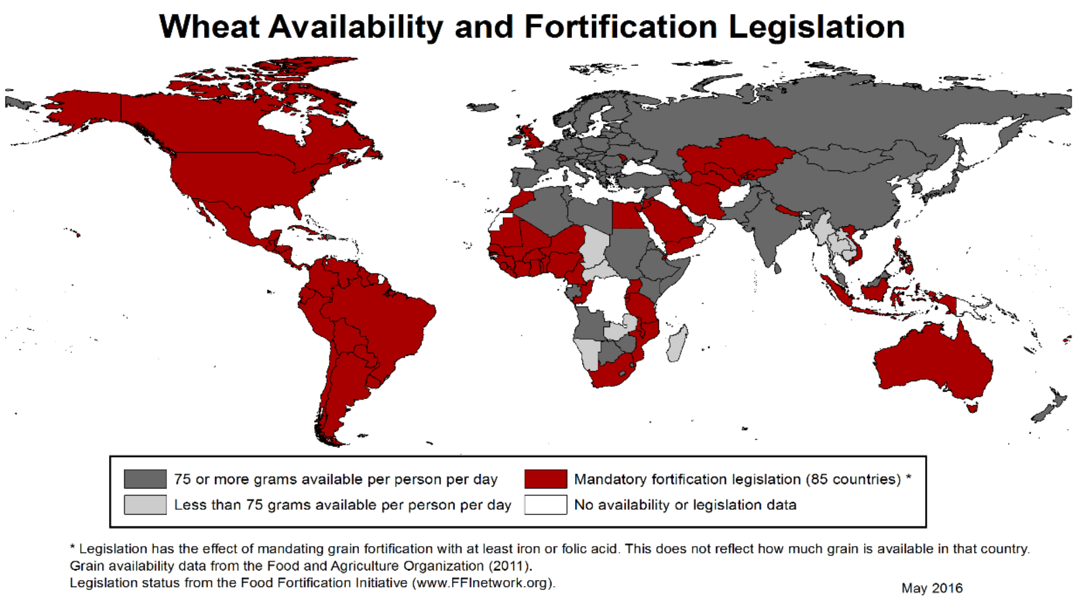

Figure 3. Countries with wheat flour legislation.
(Source: http://www.ffinetwork.org/global_progress/Wheat_May2016.png)

Technical challenges in fortifying wheat flour and other staples with iron have been described in detail in other publications (31, 32). High-extraction flour contains higher levels of phytates, which chelate minerals and thus interfere with intestinal absorption of iron (33). Although a recent study suggested this may be less of a problem, at least in anaemic women with sub-optimal iron stores than previously thought (34). The choice of a highly bio-available iron fortificant is also critically important for the success of programmes.

Several studies have been conducted to determine the efficacy and effectiveness of wheat flour fortification with iron to reduce iron deficiency and iron-deficiency anaemia (35-39). A recent systematic review concluded that the effectiveness of flour fortification for reducing the prevalence of anaemia is "limited" but evidence for reducing the prevalence of low ferritin in women was "more consistent" (40). A recent study to determine whether anaemia prevalence has been reduced among countries that fortify flour concluded (rather cautiously noting that the type of evidence used precluded a direct causal association) that anaemia prevalence had in fact decreased significantly in countries that fortify flour with micronutrients, compared with countries that do not (41). The study also found that countries that had been fortifying for a longer time were more likely to see reductions in anaemia (41).

The folic acid fortification level recommended for flour by WHO is between 1 and 5 ppm depending on the estimated per capita flour availability (42). Where initiated, mandatory fortification has substantially improved folate (and homocysteine) levels, and Neural Tube Defects (NTD) rates have fallen significantly (43, 44). A review of the prevalence of NTD cases in 27 studies, pre- and post-flour fortification and the percentile distribution of folic acid content in flour (2005–2009) using data from Argentina, Brazil, Canada, Chile, Costa

Rica, Iran, Jordan, South Africa and the USA found consistent reductions in NTD prevalence. Prevalence in Chile decreased from 18.6 to 7.3/10 000 births from 1999 to 2007 (a slight increase to 8.5 in 2008–2009, was possibly due to changes in fortification limits). The lowest prevalence was observed at a folic acid level of 1.5 mg/kg (44). Nevertheless some countries have chosen not to fortify, despite the continued evidence of impact, out of concern for potential adverse effects of long-term (and relatively high) intakes of folic acid (45).

Maize

More than 200 million people rely on maize as a staple food (46), 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 (46-48).

Sixteen countries have maize fortification programmes in place (27, 31). 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 (27). Although it is estimated that 48% of industrially milled maize flour is currently fortified (27), 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 (32). Consequently, the number of small mills without fortification technology in a country will affect whether the fortification of maize flour is a feasible option (32).

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 (27). While this might be "considered an untapped opportunity for food fortification" (27), 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 (49). Unlike other fortified food staples (such as maize or wheat), the rice grain must be directly fortified; it is not enough to fortify the subproducts (e.g. flour or porridge) (50). 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 (51). 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 (52). 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 (52).

The efficacy of rice fortification has been demonstrated. An efficacy study of fortified rice in Mexico in non-pregnant, 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 (53). The mean haemoglobin concentration was significantly increased only in those women with a baseline haemoglobin <12.8g/dl and the overall prevalence of anaemia was reduced by 80% (53). Studies in the Philippines of school-aged children with iron-fortified rice have also been found to demonstrate efficacy (54). Costa Rica has a long history of large-scale rice fortification and attributed the reduction of NTDs to its experiences with food fortification in general, as well as its centralised rice industry, government leadership, and private sector support (55). Although standards for rice fortification have been proposed (56), detailed rice fortification guidelines are in development (57). In collaboration with GAIN, the WHO convened a consultation on "Technical Considerations for Rice Fortification in Public Health" in Geneva, Switzerland on October 9–10, 2012 to provide technical inputs to the guideline development process, particularly with reference to feasibility and implementation issues (50). At the same time a Cochrane systematic review of the fortification of rice with vitamins and minerals for addressing micronutrient malnutrition was performed (58).

Large-scale fortification of condiments and edible oils

Salt

Universal iodisation of salt is the preferred strategy to control Iodine Deficiency Disorders (IDD) in most countries (59). 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 (60).

Iodine deficiency has been considerably reduced due to iodisation of salt (60, 61); 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 (62, 63). 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 (61). 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 (64). The fortification of other food vehicles with iodine has also been suggested and tested (10). There have been attempts to introduce double-fortified salt (iodine and iron) (65) and even triple-fortified with vitamin A (66). 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.

Sugar

In Guatemala and other Central American countries, vitamin A has been added to sugar since 1974 (67). Studies have shown that this has virtually eliminated vitamin A deficiency in these countries by providing children with about one-third of the recommended intake, and by facilitating an increase in the amount of vitamin A in the breast milk of lactating women. A similar finding was reported from a study in Zambia (68). Although other fortification vehicles could be considered to deliver vitamin A (69), sugar remains the most cost-efficient for Central America and has been adopted in virtually all the Central American countries since it was first launched in the 1970s.

Edible oils and margarine

Edible oils are consumed by almost everyone, usually at uniform rates in particular regions (10-20g/day in African countries and up to 70-90g/capita/day in Asia) (21) which makes them an attractive vehicle for fortification. Fortification programmes for vitamin A in fats and oils are currently in place in 41 countries worldwide. Of these countries, well over half have mandatory fortification of margarine and/or oils; eight programmes are described as “industry-led” (or voluntary); in one programme, fortification is permitted; and in seven programmes, fortification was not specified (21). It is important to note that approximately half of the countries with mandatory fortification are LMIC**.** There is a long history in Europe and some other countries of mandated fortification of margarines with vitamins A and D.

Condiments

Increasingly, condiments, spices and seasonings are being used as vehicles to increase the intake of vitamins and minerals (70). 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 [97]. Mandatory or market-driven condiment fortification with iron has been used with various vehicles: soy sauce, fish sauce, salt, and bouillon cubes (10). At least one systematic review has demonstrated that iron fortification of condiments is associated with increased haemoglobin, improved iron status, and reduced anaemia across targeted populations (15). 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 (71).

4. Components of successful food fortification programmes

The fundamentals of a successful fortification programme (including technical instructions, appropriate fortificants, and monitoring and evaluation) have been described in detail in the WHO/FAO guidelines on food fortification with micronutrients (10). When developing a mass fortification programme, there are four key elements that must be in place and protected throughout the process. This includes operational research, design, development, programme implementation and scale-up (see Figure 4).

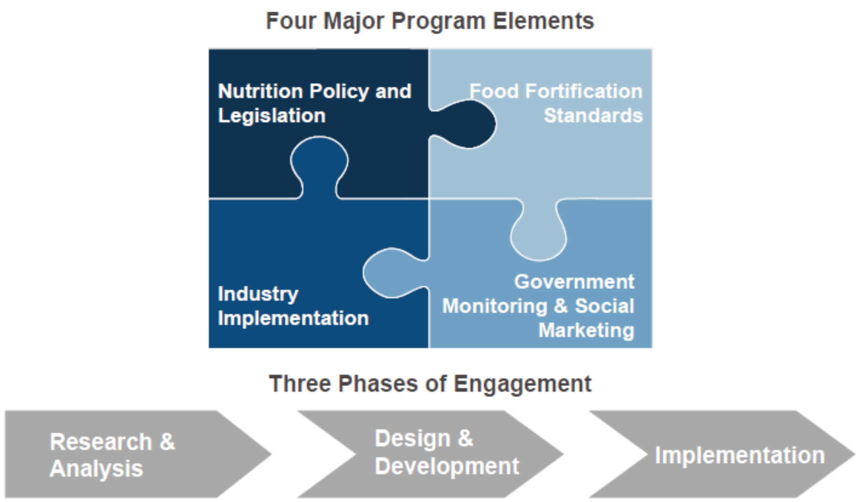

Figure 4. Major programme elements in the development of large-scale food fortification programmes

(Used with permission from Rowe & Dodson [18])

Successful programmes are built around multi-sectoral foundations including government, private sector, international organisations, civil society and academia, all working together to generate evidence identifying the need, setting standards, ensuring legislation and alignment with national nutrition policies, ensuring quality assurance and control throughout the manufacturing processes, and establishing strong monitoring and evaluation to ensure compliance and impact (see Figure 5).

Establishing food fortification standards, legislation and regulation

When implemented within a comprehensive nutrition strategy, fortification has the greatest potential to improve the nutritional status of a (7, 72). In a discussion of the role of governments and academics, Harvey and Dary (73) describe key issues that governments need to address to ensure a sustainable programme. Harvey and Dary cite the identification of the right food and fortificant (accounting for bioavailability, interaction with food, availability, acceptability, and cost) and target population, ensuring quality of product, and consumption of sufficient quantity of the fortified foods. To accomplish these aims – and to ensure sustainability – there must be a demand that is sustained through behaviour change communication at the consumer level and a ready access to a sufficient supply of products. Standards set through a legislative process, from production to point-of-consumption, must be maintained (73, 74). To ensure a competitive market, government monitoring of standards-compliance, and public-private partnerships, is essential (72).

Fortification can be either mandatory or voluntary; in either case, appropriate legislation is required to ensure impact and safety. In addition, for voluntary fortification programmes, governments need to ensure that the programme is consistent with their national nutrition policies and that consumers are not misled by either the fortification practices or the claims made on the product packaging (10).

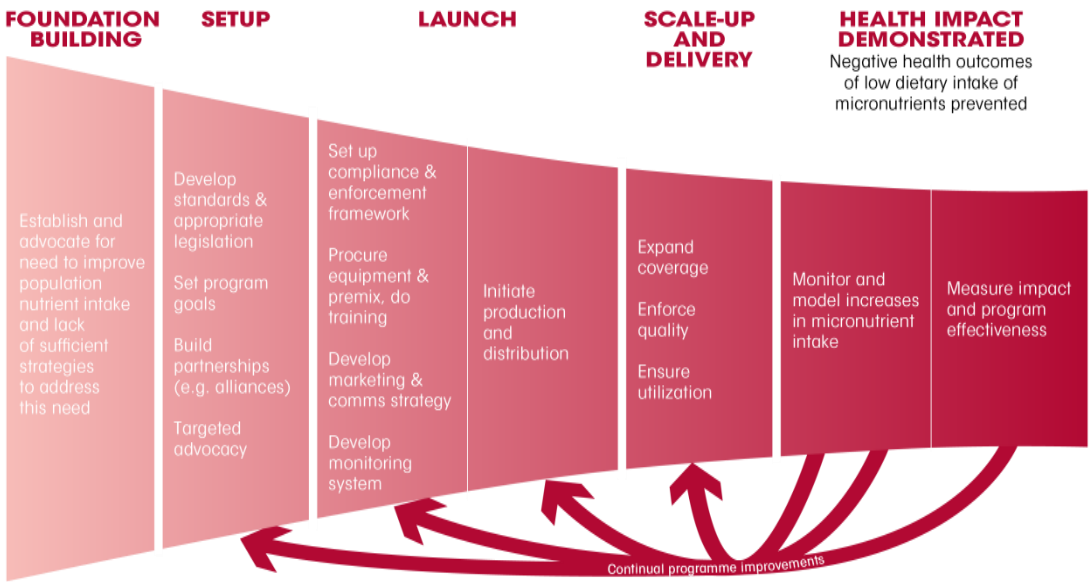

Figure 5. Impact model for staple food fortification programmes

(Used with permission from GAIN)

Monitoring, quality assurance and quality control, and impact evaluation

For mandatory fortification to work, consistent and effective monitoring is necessary to ensure both quality assurance and quality control (QA/QC), as well as consumption by the target population (10). Internal and external QA/QC will need to be in place at the inception of any fortification programme to ensure compliance with standards. In addition, monitoring and evaluation to assess the degree to which the fortified food is actually reaching households and individuals (and thus presumably achieving its nutritional goals) will need to be in place in order to address issues of potential for impact and utilisation across different population subgroups. It is also critical for providing programme planners and policy-makers with the necessary information to make decisions about course correction, scaling up and termination of a programme (10).

Quality assurance and control during product manufacturing, and distribution must be in place. Procedures on good manufacturing practice are available through the International Organization for Standardization (ISO)and described in the WHO/FAO guidelines (10). Sufficient budget will need to be in place to ensure compliance and enforcement. A review of external quality assurance and quality control activities in GAIN-supported staple food fortification programmes in 25 countries found that the percentage of foods that were adequately fortified (also known as the external pass rate) ranged from 18% to 97%, with the average falling between 45% to 50% (75). Many of these non-compliant fortified foods were found to be labelled as compliant, further misleading consumers on vitamin and mineral content and contributing to a reduced health impact of fortification programmes (76).

There are five underlying issues that are leading to poor compliance in these 25 country programmes supported by GAIN (75):

1. Food laws and regulations related to monitoring, inspection, and enforcement are too often fragmented and not appropriately set within legal frameworks, leading to weak or non-existent enforcement;
2. Food safety and quality control practice and culture do not prioritise fortification, especially where resources are limited. Over 80% of government respondents noted that their current funding was not sustainable over the next five years;
3. Political risk in enforcing compliance with regulations. Even where resources and capacity exist, over 60% of respondents thought that regulatory agencies are often unwilling to enforce regulations due to perceived or real resistance from interest groups;
4. Cost to industry to fortify and some industries lack appropriate internal budget and expertise to fortify appropriately while others purposely under-fortify; and,
5. Fortified food is a type of credence good, meaning that consumers must trust what is stated on packages in relation to vitamin and mineral content. Often, regulatory monitoring agencies and consumer protection groups do not actively protect consumers from under-fortified or non-fortified foods, or fraudulent labelling.

Programme impact evaluations are required to provide evidence that the programme is reaching its nutritional goals. Evaluations are more likely to be useful when based upon a sound programme theory with “a causal pathway developed explicitly to identify the critical points through which a programme is predicted to provide the desired impacts” (73).

5. Challenges

While numerous studies and reports attest to the effectiveness and feasibility of fortification (10, 37, 77, 78), there are challenges that remain.

Evidence gaps

There are still evidence gaps with respect to the potential for impact on public health, as well as how to effectively measure the impact. While the effectiveness of food fortification on nutrient intakes and nutrient status is well established, there is still insufficient evidence of effectiveness on functional outcomes, including growth, cognitive development, morbidity and mortality, especially in LMIC (11, 79). This is an issue especially since much emphasis is currently being placed on the prevention of stunting. The translation of evidence into realistic target settings for policies and programmes is often lacking. In addition, changes in dietary habits over time may results in challenges (as in the case of decreasing consumption of iodised table salt in Europe (80) as well as opportunities (with fortified breakfast cereals now being the primary source of iron for school-children in the UK (14).

Following a recent consultation, research gaps on technical issues with fortification were identified (especially for rice fortification) (81). Further evidence was also needed on:

i. Determining the stability of different micronutrients in various context-specific environments;
ii. Studying the nutrient-nutrient interaction so as to better understand relative bioavailability and phytate effect on iron absorption; and
iii. Evaluating the optimal delivery platforms for reaching the target populations.

There are still numerous technical issues, as well as a lack of technical expertise and fortification equipment in small local production mills and small-holding salt production units. This is especially a concern because small-scale mills are the predominant source of (iron-fortified) wheat and maize flours in rural subsistence farming areas, while small-holding salt production units require small-batch iodisation.

Ensuring effective coverage

Effective coverage is defined as proportion of the population which uses an intervention with the intent to achieve a biological/health impact (82). For food fortification this could be interpreted as the proportion of the population consuming adequately fortified food (83). Effective coverage is a precondition for impactful programmes, as are other factors described in this report. Challenges in reaching impact have been described from the very early days of large-scale fortification programmes in the US. Such challenges, including choosing appropriate fortification vehicles, not reaching populations most likely to benefit, avoiding overconsumption in non-targeted groups, and adequate monitoring of nutritional status, currently still exist in all countries (22).

Ensuring quality control and monitoring

Many national programmes are currently not achieving national targets, especially in iodine "because of weak regulatory/monitoring systems" (*Yusafali, personal communication* cited in (23)). Establishing effective monitoring systems and tools for assessing quality control and compliance, as well as setting up rigorous impact evaluations, require a thorough understanding of the different pathways leading to effective coverage and impact. Insufficient budgets are often identified as constraining adequate quality control and compliance (75).

Accessibility and equity

One of the criticisms of mass fortification is that it may not be accessible to those who need it most. Commercially fortified products may not be affordable for the poorest segments of societies, partly because in some countries, import duties and taxes on premixes or fortification equipment drive prices up. Inequity in access to fortified foods must be researched within the specific local context, as reasons for lack of accessibility will differ within countries and within households. Programmes often lack such particular understanding and do not assess intra-household food distribution practices, which often place women and young children at a disadvantage within the household (84, 85). To effectively reach populations most in need, opportunities to link with related programming (for example social protection programmes) will need to be explored and better utilised.

6. Conclusions

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 iodisation of salt, starting in Switzerland in 1924 and introduced in the USA soon after, has been one of the great public health success stories of the world. In the last two decades, large-scale food fortification initiatives have also been reaching large segments of populations in LMIC. At the same time, we have witnessed an acceleration of knowledge and guidance on large-scale fortification. Despite these advances, a number of technical and social challenges continue to limit progress and potential of impact, particularly among vulnerable populations. Nevertheless, the number of people reached by mass fortification has also expanded enormously, along with the resulting positive health and development consequences globally. Importantly, much of the recent progress has been in LMIC where the need is greatest.

The purpose of the #FutureFortified 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. It included five critical areas to address for immediate progress:

1. Modest but new investments
2. Improvements to the oversight and enforcement of food fortification standards and legislation
3. Generation of more evidence to guide fortification policy and programme design
4. More transparent accountability and global reporting
5. Continuing advocacy (13)

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