Symposium: Food Fortification in Developing Countries

The Economics of Food Fortification[1]

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ABSTRACT This paper summarizes some of the literature on the cost effectiveness and cost benefit of food fortification with selected micronutrients most relevant for developing countries. Micronutrients covered include iron, iodine, vitamin A, and zinc. The main focus is on commercial fortification, although home fortification and biofortification are mentioned. Fortification with iron, vitamin A, and zinc averts significant numbers of infant and child deaths and is a very attractive preventive health-care intervention. Fortification with iron, iodine, and potentially zinc provides significant economic benefits and the low unit cost of food fortification ensures large benefit:cost ratios, with effects via cognition being very important for iron and iodine. Fortification will not reach all individuals and is most attractive as an investment where there is a convenient food vehicle, where processing is more centralized, and where either the deficiency is widespread or the adverse effects are very costly even though only a small group is affected. J. Nutr. 136: 1068–1071, 2006.

KEY WORDS: • *food fortification* • *cost-effectiveness* • *benefit:cost* • *micronutrients*

The economics of food fortification has played an important role in its implementation in public policy. Cost effectiveness [as measured by cost per death averted or cost per disability-adjusted life-year (DALY)[3] saved] has helped to give fortification high priority as a preventive health-care intervention. High benefit:cost ratios (comparing the economic benefits and costs of fortification) have likewise put fortification in the forefront in public policy regarding social sector investments.

The high return to micronutrient investments was recognized, for example, at the Copenhagen Consensus (1), where micronutrients are ranked by experts as one of the top four "very good" priority development interventions, along with control of human immune deficiency virus/acquired immune deficiency syndrome (HIV/AIDS), trade liberalization, and malaria control. (By comparison, of the 17 interventions considered in total, agricultural technology to reduce malnutrition was included as "good" and interventions to reduce low birth weight and to improve infant and child malnutrition were ranked only as "fair").

This paper summarizes some results for the big three micronutrients of most concern in the developing world, namely, iodine, iron, and vitamin A, as well as zinc, which is an emerging concern, with some comments about folic acid. Other micronutrients of possible interest include other B vitamins, vitamins C and D, and minerals such as calcium, fluoride, and selenium, but little economic analysis is available.

The focus is primarily on commercial fortification, although home fortification and biofortification are also considered. Home fortification involves adding a micronutrient preparation to home-prepared food; biofortification involves selective breeding or genetic modification to produce higher micronutrient varieties.

The following four sections present data on cost effectiveness of fortification (using cost per DALY saved as the metric), benefit:cost ratios for fortification, a brief discussion of other forms of fortification, and, finally, some conclusions.

Cost effectiveness. One source of consistent estimates for cost effectiveness of micronutrient interventions is the World Health Organization (WHO)-CHOICE (CHOosing Interventions that are Cost Effective) (2). These estimates are not directly obtained from interventions, but are constructed from what is known about cost of interventions, effectiveness (in terms of micronutrient status) of interventions, and links between micronutrient status and morbidity/mortality outcomes. The data on micronutrient status and morbidity/mortality linkages are summarized in **Table 1**.

The results depend crucially on the assumptions made and cost effectiveness varies according to the environment (degree of micronutrient deficiency, presence of other inhibitors in the diet, confounding factors such as infection and malaria prevalence for iron deficiency, for example, and factors such as population density and internal transport costs that affect the costs of intervention). The results should be taken as implying

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[3] Abbreviations used: DALY, disability-adjusted life-year; HIV/AIDS, human immune deficiency virus/acquired immune deficiency syndrome.

TABLE 1

Summary of effects of micronutrient deficiency

Micronutrient	Effects on morbidity/mortality	Economic impact
Vitamin A	Relative risk of mortality (deficient vs. nondeficient) is 1.75:1 (3)	n.a.
Iodine	n.a.	Productivity loss to children of mothers with goiter on average 10.273% (4)
Iron	1 g/dL increase in hemoglobin associated with odds ratio for perinatal mortality of 0.72 and for MMR of 0.75 (5)	Productivity loss associated with anemia is 5% (light manual work), 17% (heavy manual work), 4% (other work via cognitive effects) (6)
Zinc	Odds ratio for mortality due to diarrhea of supplemented vs. unsupplemented children 6–24 months in population with deficiency (Pakistan) 0.82 (7); odds ratio for pneumonia incidence 0.75 from meta-analysis: (8)	Productivity loss due to lower stature not fully quantified; suggestion of cognitive effects a long way from quantification

n.a., Not applicable; MMR, maternal mortality rate.

broad relative rankings for interventions and fine differences in cost effectiveness are probably not very meaningful.

The advantages of the CHOICE database include the fairly broad coverage of interventions, the use of consistent methodology, and the ability to customize the results to different WHO subregions. The disadvantages include the lack of documentation of methods on the site and (in this author's opinion) the low estimates of costs (hopefully, these are consistently low across interventions). For example, the iron estimation methods have been published (9) and focus on elemental iron, which is the cheapest iron fortificant, although it is not highly bioavailable and hence not generally preferred in program use.

Results for one sample region (Africa E) for fortification and supplementation with iron, vitamin A, and zinc, assuming 80% coverage, are shown in **Figure 1** (WHO also presents estimates for 50% coverage that tend to be a little higher, but not >25% higher, and typically the relative rankings do not change). The costs per DALY saved are very modest (lower for fortification than for supplementation by a factor of at least 2 and up to 10). Because supplementation is more costly than fortification, its recommended use depends on circumstances. If the deficiency is not widespread across the population, but there is a narrowly defined target group that can be reached readily without compliance issues, supplementation may be preferable. This is the case, for example, with high-dose vitamin A supplements for young children, where the doses can be administered in combination with immunization.

The cost-effectiveness figures for fortification (ranging from $22 to $60 per DALY saved, depending on the micronutrient) compare favorably with those for other cost-effective primary health-care interventions for children ($85/DALY for case management for pneumonia, $152/DALY for oral rehydration therapy for diarrhea, also calculated assuming 80% coverage).

The costs per DALY saved tend to be a little higher in other regions with less adverse mortality experience than Africa E and depend on prevailing patterns of micronutrient deficiency. Africa E, when compared with Latin America B for fortification, shows that iron fortification is the highest priority in Africa E and zinc is the lowest, whereas the opposite is the case in Latin America B (**Fig. 2**). The overall conclusion—that fortification is highly cost effective—however, remains unchanged.

Benefit:cost. There is no single source with comparable benefit:cost estimates for several micronutrient interventions (much less a source that allows estimates to be generated for different regions with different levels of deficiency and different wage and price structures). The view from the literature is that the benefits of investments in micronutrient fortification far outweigh the costs (the costs tend to be a few cents per person per year). Horton (10) makes very rough estimates of the annual potential costs attributable to iodine deficiency in the developing world: $35.7 billion prior to widespread salt iodization, as compared with an estimated $0.5 billion annual cost for salt iodization, i.e., a 70:1 benefit:cost ratio. Horton and Ross (6) undertake a more detailed incidence study for iron fortification and estimate that the benefit:cost ratio has a median value of 6:1 for effects on physical productivity, which rises to 36:1 if cognitive benefits are also included. Estimates for zinc, taking into account effects via reduced stunting, are in preparation.

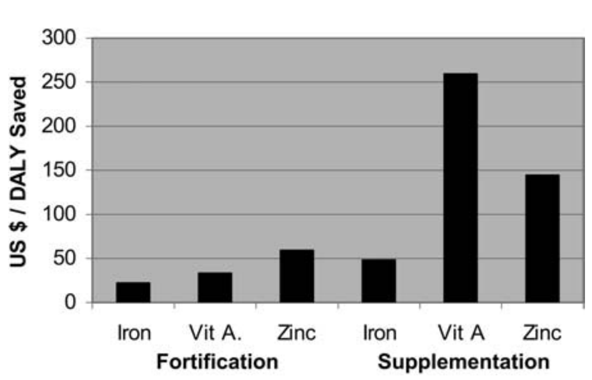

FIGURE 1 Cost per DALY saved, Africa E, micronutrient interventions.

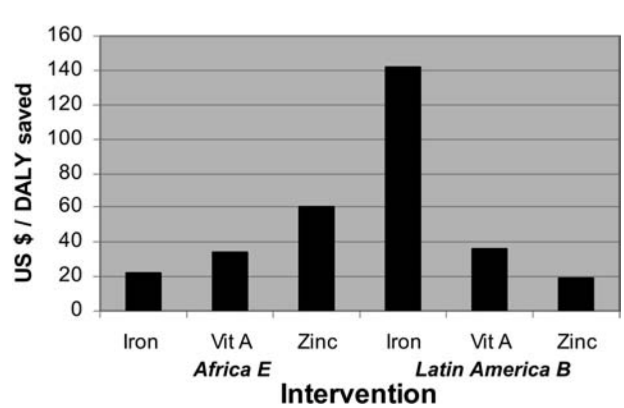

FIGURE 2 Comparison of cost effectiveness of fortification, two regions.

These estimates rely heavily on the assumptions regarding the effects of food fortification (on cognitive ability and physical productivity) included in Table 1, as well as the assumptions about program costs of fortification and its effectiveness (in terms of reduction of micronutrient deficiency), summarized in **Table 2**.

Another area where cost savings (in terms of reduced hospital costs) may be substantial compared with the costs of fortification is that of fortification of wheat flour with folate. This extends to several industrialized countries at present, and Chile is one of the first developing countries to undertake such fortification. No benefit:cost estimates are available for developing countries as yet. They are probably lower than in the developed countries because the level of spending on individuals with birth defects is lower, but likely remain a very worthwhile social investment.

Other forms of fortification. The results presented so far are based on commercial fortification programs. There are various alternatives. Fortification has been undertaken at more local levels, such as in refugee camps. Operating on a smaller scale is likely to increase the costs of fortification somewhat, but this may well remain an important social investment, although this does not obviate the need to provide refugees with an adequate and varied diet.

Home fortification is another possibility, whereby micronutrient preparations are added to food in the home. There have been pilot interventions involving "Sprinkles," which may contain iron, zinc, iodine, vitamins A, C, and D, and folic acid, that have been targeted to weaning-age children. The unit costs tend to be higher than for commercial fortification. On the other hand, the intervention can be targeted to weaning-age children who are particularly vulnerable to deficiency and who are unlikely to obtain enough of selected micronutrients from foods fortified for the general population.

TABLE 2

Summary of assumptions regarding effectiveness and program unit costs of fortification

Micronutrient	Assumption
Iodine	Universal salt fortification completely eliminates goiter in the long run
Iodine	Cost approximately $0.10/(person·year) for salt (11)
Iron	Fortification of wheat flour reduces prevalence of anemia by nine percentage points for benefit:cost calculations (6)
Iron	Fortification reduces perinatal and maternal mortality by one-third for cost per DALY calculations (5) (supplementation assumed to reduce mortality by two-thirds)
Iron	Cost approximately $0.12/(person·year) for wheat flour (12)
Vitamin A	Fortification of foods consumed by infants and children ages 6 to 24 months can be adequate to eliminate subclinical vitamin A deficiency (same for high-dose supplementation at 6, 12, and 18 mo)
Zinc	"Home fortification" with 5 mg of zinc gluconate administered 60 times over a 4-mo period is enough to protect children from higher diarrhea risk in situations of intermediate/high deficiency
Zinc	Cost approximately $0.90/child for 2-mo course (annual cost would be 6 times this) for home fortification including other micronutrients (7); fortification cost of wheat flour with zinc sulfate approximately $0.24/(person·year) (author's estimate); zinc oxide could be as low as $0.06/(person·year) (author's estimate)

Estimates for Sprinkles for Pakistan, when primarily targeted to children 6–12 mo (7), suggest that cost per DALY saved could be as low as $12 (based on the effects of zinc on averting diarrhea), and the benefit:cost could be 37:1 (based on the effects of iron on future productivity due to cognitive benefits), which are quite similar to estimates for commercial fortification. These estimates are based on intervention trials rather than a full-scale program and are for a country with high levels of deficiency, high infant mortality rates, and high rates of diarrhea. Larger scale trials would be worthwhile.

Another promising avenue is biofortification, whereby higher micronutrient density is either bred, or introduced via genetic modification, into staple food crops. Biofortification of rice is of particular interest because it is more difficult and costly to fortify rice by conventional means than the other grains. Preliminary work suggests this could be very cost effective. For rice, high iron varieties have been identified and feeding trials have shown the iron to be bioavailable and to lead to higher body iron levels (13). Initial work is also under way for five other staples.

Detailed cost-effectiveness estimates for biofortification are not available; however, Bouis (14) makes the provocative calculation of what $80 million could buy. It could provide vitamin A supplementation (capsules) to 80 million children in South Asia for 2 y (one-fifteenth of the population); it could provide iron fortification to one-third of the population of South Asia for 2 y; or it might be possible with this funding to develop six nutrient-dense crops for dissemination to all the world's people for many years.

Conclusions. Economic analysis suggests that fortification is indeed a very high-priority investment. Of course, the long-run aim is to diversify people's diets such that most of their needs can be met from food. Fortification cannot solve all micronutrient problems. There are selected population groups who will continue to need additional measures, for example, pregnant women (fortification cannot safely supply all the needs for iron for this group, for example), and weaning-age children.

Fortification works well if there are widespread deficiencies (e.g., iron) and/or if the cost of the fortificant is not too high (cost becomes a problem for calcium at the volumes required, and for vitamin C, where cost is exacerbated by overage requirements related to storage losses). Fortification is particularly attractive if the cost of the deficiency is very high and it is not easy to reach the target group (women periconception): this applies particularly for folic acid and iodine.

Fortification requires a suitable food vehicle. There are populations that are hard to reach with commercial fortification, particularly those living in more remote geographic areas and not utilizing purchased foods. It is harder to reach the poorest who are the most price sensitive and who buy lower grade items that are less likely to be fortified, as shown clearly for iodized salt (15).

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