Cost-effectiveness of Biofortification

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Cost-benefit analysis (CBA) is often used to calculate and compare benefits and costs of a project, decision, government policy, or intervention (hereafter, “intervention"). CBA has two purposes: to determine if the intervention is a sound investment and to provide a basis for comparing interventions. CBA involves comparing the total expected present cost of each intervention against the total expected present benefits to see whether the benefits outweigh the costs and by how much. For CBA, costs as well as benefits have to be expressed in monetary values. Cost-effectiveness analysis (CEA), on the other hand, compares the relative costs and outcomes (benefits) of two or more interventions. The intervention that achieves a certain (non-monetary) outcome at the least cost is usually preferred. In health literature, Disability-Adjusted Life Years (DALY) is often used to measure the outcomes of health interventions. The DALY is a measure of the overall disease burden of a particular condition (such as micronutrient deficiencies), expressed as the number of years lost due to ill-health, disability, or early death, according to the severity of the adverse health outcomes it entails.

With the metric “costs per DALY saved,” the costs of biofortification can be compared with other interventions, such as fortification. The World Health Organization’s CHOICE (Choosing Interventions that are Cost Effective) Working Group has suggested that a health intervention should be considered “very cost-effective” if its cost per DALY saved is less than national per capita income, and “cost-effective” if it is between 1 to 3 times per capita income.

Several CEAs have been conducted to gauge the feasibility and desirability of biofortification interventions (i) across micronutrient-country-crop combinations and (ii) compared to other micronutrient interventions within a country (1). The majority of these CEAs are *ex ante* (before the event) and are based on assumptions and projections of the future costs and coverage (adoption and consumption rates) of biofortification. These CEAs have long time horizons (about 30 years), as it takes time for the suitable biofortified varieties to become available, to be adopted and consumed at a scale, and for health benefits to surface among the consuming population.

A recent study by Fiedler and Lividini estimates the *ex ante* effects of vitamin A orange maize, as well as five other interventions, such as fortified oil, sugar, and wheat flour in Zambia (2). It assesses the cost-effectiveness, total costs, and total number of DALY saved from single interventions and from combinations of different interventions. The cost per DALY saved through vitamin A orange maize was estimated at US$24. Moreover, several of the intervention combinations cost less than US$50 per DALY saved. Perhaps the most important finding is that a combination of biofortification with some form of fortification can result in lower costs per DALY saved while increasing total numbers of DALY saved within a given budget. Biofortification is found to be especially cost-effective for maize-producing farmers whose families consume maize from their own production. Fiedler and Lividini also focus on zinc rice and zinc fortification of wheat flour in Bangladesh (2). Preliminary results reveal that the cost per DALY saved through zinc rice is less than one-third of the cost per DALY saved through fortification of wheat with zinc, suggesting that biofortification of rice is the most cost-effective, long-run strategy to sustainably reduce zinc deficiency in Bangladesh.

The preliminary results from recent *ex ante* CEAs on zinc and vitamin A crops are reported in the table below. For all crop-country combinations, biofortification can be rated as very cost-effective, as costs are significantly below per capita income, which ranges from US$365 in the Democratic Republic of Congo (DRC) to US$3,843 in India. When compared to fortification, biofortification is found to be more cost-effective for all crop-country-micronutrient combinations. Moreover, for all cases except one, biofortification is more cost-effective than supplementation.

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Country	Micronutrient	Biofortification Cost per DALY Saved*	Fortification Cost per DALY Saved**	Supplementation Cost per DALY Saved***
Bangladesh	Zinc	Rice: $11-32	Wheat: $19	$7
India	Zinc	Rice: $0.6-2	Wheat: $16	$7
Pakistan	Zinc	Wheat: $3-18	Wheat: $27	$58
India	Zinc	Wheat: $1-4	Wheat: $16	$7
DRC	Vitamin A	Cassava: $0.4-1	Sugar: $37	$52
Nigeria	Vitamin A	Cassava: $0.3-0.5	Sugar: $50	$52
Ethiopia	Vitamin A	Maize: $2-6	Oil: $43	$52
Zambia	Vitamin A	Maize: $9-30	Wheat: $12	$52
Uganda	Vitamin A	Sweet potato: $4-7	Sugar: $56	$52

* Preliminary results by Birol et al. (2014) (3); ** Fiedler and Macdonald (2009) (5); ***WHO CHOICES (50% coverage) (5).

Ex post (after the event) CEA seeks to measure cost-effectiveness of an already implemented intervention and uses actual data on the costs and coverage (adoption and consumption) rates of the intervention. The CEA of the Reaching End Users in Uganda with orange sweet potato (OSP) project (2006–2009) found this intervention's cost per DALY saved to be in the range of $US15–24 (6). Further evidence on *ex post* cost-effectiveness of biofortified crops will be built in the coming years.

The CEA thus far conducted reveals biofortification to be a highly cost-effective strategy for reducing micronutrient deficiencies. It is, however, important to note that the cost per DALY saved cannot be used as the sole criterion for determining the most appropriate micronutrient intervention, as it does not consider the total number of DALY that can be saved under a given budget. A given intervention may be inexpensive but may also have small coverage and save only a few DALY. Likewise, an intervention that is more cost-effective overall may be relatively less cost-effective in certain scenarios (target groups, time horizons, available infrastructure, etc.). Therefore, a combination of biofortification, supplementation, and fortification may be best for achieving cost-effective and large scale impact. The cost advantage of biofortification comes from the economies of scale (once a new crop has been developed, its benefits can be spread relatively cheaply over time and space) and lies in its ability to reach a high number of rural (farming) households who produce and consume large amounts of staple food crops and who suffer from micronutrient deficiencies.

Biofortification interventions exhibit relatively high up-front costs in the first six to ten years. These costs depend on many factors, such as the type of crop and micronutrient, size of the target country, research infrastructure, and seed sector. As HarvestPlus and its partners make further progress in breeding and identifying cost-effective models for delivery, the costs to cover new regions and countries will decrease. In these new countries, however, there will still be the costs of adaptation and maintenance breeding and the setting up of seed multiplication and delivery channels. These costs could, to some extent, be alleviated through cross-country learning and spillover. The early phases of biofortification interventions generate public goods (e.g., knowledge about biofortified crops, breeding lines with high micronutrient content), which will need to be financed by governments and donors. In later phases, nutritional value becomes a standard target (i.e., mainstreamed) in public breeding programs, and biofortified germplasm is shared with the private sector, which can integrate it in its breeding programs. In the long run, biofortification can be self-sustaining.

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5. WHO CHOICES. http://www.who.int/choice/en/
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