Functional Food for the Poor:
the Potential Impact of "Biofortification" on Public Health in India

Alexander J. Stein[a], Matin Qaim[a] and J.V. Meenakshi[b]

[a] University of Hohenheim, International Agricultural Trade and Food Security (490b), 70593 Stuttgart, Germany
[b] International Food Policy Research Institute (IFPRI), HarvestPlus, Washington, DC 20006-1002, United States

Abstract: Micronutrient malnutrition affects billions of lives. Combating this hidden hunger *is mainly done through pharmaceutical supplementation and industrial fortification. More recently addressing this issue through agriculture was proposed, namely* biofortification *of staple crops, i.e. breeding food crops for higher levels of micronutrients. Yet, knowledge about the cost-effectiveness of biofortification is limited. This study analyses the expected costs and benefits of iron-rich and zinc-rich cereals in India. To quantify the health benefits a disability-adjusted life year (DALY) framework has been deployed. Representative data on household food consumption has been used to derive individual nutrition statuses in the* status quo *and for two future scenarios in which biofortified cereals are consumed. Improvements in these statuses have been translated into reductions in related morbidity and mortality. It could be shown that iron-rich as well as zinc-rich rice and wheat have the potential to reduce the respective deficiency. The costs per DALY saved fall below the World Bank's cost-effectiveness threshold; biofortification can considered to be effective and economical.*

Keywords: biofortification, micronutrient malnutrition, plant breeding, staple crops, DALYs, health benefits, cost-effectiveness analysis, India

Introduction

There are an estimated 800m undernourished people in the developing world. Yet, the problem of *hidden hunger* – or micronutrient malnutrition – is even larger: 4-5 billion people are affected by iron deficiency (ID), 2.7 billion are zinc deficient, 2 billion suffer from iodine deficiency, and 140m children are deficient in vitamin A (ACC/SCN 2004, WHO 2002).

Relying on economic development and income growth alone is not likely to rid the world of this problem any time soon (Haddad et al. 2003). However, apart from iodised salt, the success of current interventions to combat micronutrient (MN) deficiencies in developing countries – mostly pharmaceutical supplementation and industrial fortification – has been mixed (ACC/SCN 2004). A more recent proposition relies on agricultural research and development (R&D) to improve the MN status of target populations: HarvestPlus, a CGIAR programme, promotes efforts to *biofortify* food crops (CIAT/IFPRI 2004). This new strategy refers to breeding staple crops for higher MN levels, as these crops are eaten by poor people who cannot afford a more nutritious and diverse diet. Higher MN levels bring a health benefit beyond that of the conventional crop, which makes biofortified crops *functional food* (e.g. Milner 2000). In principle, once such crops are developed and successfully disseminated, they can be reproduced by farmers and automatically form part of the food chain. Hence, for a largely one-time investment this strategy can produce a stream of future benefits to consumers of these crops. While this reasoning is intuitive, there has been no other attempt to quantify the health benefits of iron-rich and zinc-rich cereals

explicitly or to determine the cost-effectiveness of this approach. This is what the present study aims to do for India, where 26% of the population is estimated to be at risk of inadequate zinc intake (Hotz and Brown 2004) and where about 50% of women and 74% of children are anaemic (IIPS 2000)[1].

To quantify health benefits we use *disability-adjusted life years* (DALYs), a metric that was so far primarily used in health economics but that was adapted to a model for the analysis of bio-fortified staple crops (Stein et al. 2005). Here this model is applied for measuring the current burden of both MN deficiencies and the potential impact of the biofortified cereals on public health. To derive this impact in a precise manner, consumption data of a representative data set, with observations from 120,000 households in India, is used. In the following sections we describe the DALY methodology, present estimates of the burden of ID and zinc deficiency (ZnD) in India, consider potential reductions in these burdens under 2 scenarios, quantify the cost-effectiveness of biofortification and compare these results with cost-effectiveness standards set by international organisations.

Method and data used

The *World Development Report 1993* (World Bank 1993) and *The Global Burden of Disease* (Murray and Lopez 1996) have introduced and familiarised DALYs. In the context of a cost-benefit analysis Zimmermann and Qaim (2004) have used DALYs for the first time to assess a biofortified crop. Compared to alternative measures that value health interventions, like cost-of-illness or willingness-to-pay approaches, DALYs are more equitable because they do not rely on the financial capacity or the economic potential of the affected individuals. Hence, health is not valued differently for different individuals. With DALYs different health outcomes can be quantified in a standardised manner, according to their respective severity. This is achieved through the weighting of years of life lived with disabilities resulting from a specific cause. These *disability weights* are defined for a range of 0 to 1, with 0 representing perfect health and 1 representing a health status equal to death; this is how the effect of both morbidity and premature mortality can be measured in common units.

The total burden of a disease is the sum of *years of life lost* (YLL) due to cause-specific mortality and the weighted *years lived with disability* (YLD) (Murray and Lopez 1996). That is,

(1)   *Burden of disease = DALYs$_{lost}$ = YLL + YLD*

Taking account of different incidence rates and levels of severity of a disease between different groups within a population, the complete formula can be represented more formally as:

$$(2) \quad DALYs_{lost} = \sum_j T_j M_{ij} \left(\frac{1 - e^{-rL_j}}{r} \right) + \sum_i \sum_j T_j I_{ij} D_{ij} \left(\frac{1 - e^{-rd_{ij}}}{r} \right)$$

where T_j is the total number of people in target group j and M_{ij} is the mortality rate associated with a given disease i, I_{ij} is the incidence rate of that disease, D_{ij} is the corresponding disability weight, and d_{ij} is its duration. For permanent disabilities d_{ij} equals the average remaining life expectancy L_j. Future life is discounted at the rate of r (Zimmermann and Qaim 2004).

Adverse functional health outcomes that are associated with ID are calculated separately for moderate and severe iron deficiency anaemia (IDA) and comprise (i) impaired physical activity, (ii) impaired mental development, and (iii) maternal mortality, which leads to stillbirths and child deaths; outcomes that are associated with ZnD are (i) increased child mortality, (ii) diarrhoea, (iii) pneumonia, and (iv) stunting. More details as well as a more detailed discussion of the DALY methodology can be found in Stein et al. (2005). Information on population size, incidence rates and life expectancies were taken from appropriate statistics (IIPS 2000, Census 2001, WHO 2001, NIN 2003. UNICEF 2004).

Comparing the burden of a deficiency in the *status quo* with its burden in a scenario where biofortified crops have been introduced gives their health impact expressed in *DALYs saved*. To

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[1] Anaemia can be caused by multiple factors, but ID is the most important one.

analyse ID, data on prevalence rates of IDA is matched with the intake of iron at the level of individuals and thresholds for moderate and severe IDA in each target group and for three dietary regions within India are generated. When iron-rich cereals are consumed, fewer people fall below these thresholds; from this, new prevalence rates can be derived and used in the DALY calculation.[2] To analyse ZnD, the efficacy of zinc-rich cereals in closing the gap between actual zinc intake and requirements is computed and the relative reduction of this gap is used to derive reductions in the incidence rates of the health outcomes of ZnD (Stein et al. 2005). Individual intakes of these MNs in the *status quo* are derived by means of food composition tables and adult equivalents from data of a representative survey of 120,000 household that recorded the consumption of 140 food items (NSSO 2000). Because neither iron-rich nor zinc-rich cereals have been released yet, an optimistic and a pessimistic future scenario is used in each case to take account of uncertainties related to an *ex-ante* analysis. The new intake of each MN is calculated based on the assumptions given in the table below and calculated thus:

(3)   *new MN intake = MN intake in* status quo +
      *+ (current intake from crop * increase in MN content * production share of crop)*

Optimistic and pessimistic assumptions used the derive new intakes of iron and zinc

Crop	Scenario	MN content in grain	Increase in MN content	Production share 20 years after release
Iron-rich rice	pessimist./ optimistic	3 ppm (polished)	100-167%	20-50%
Iron-rich wheat	pessimist./ optimistic	38 ppm	20-60%	30-50%
Zinc-rich rice	pessimist./ optimistic	13 ppm (polished)	54-169%	20-50%
Zinc-rich wheat	pessimist./ optimistic	31 ppm	20-120%	30-50%

Source: Personal communication, G. Barry (IRRI) and I. Ortiz-Monasterio (CIMMYT), 2005.

To establish the cost-effectiveness of the biofortification efforts, a share of R&D costs at the international level is attributed to India and added to national R&D and maintenance costs. Because the biofortification strategy involves breeding MN-rich *and* agronomically superior crop varieties as part of ongoing research efforts at national agricultural research systems, no extra costs for marketing or extension will be incurred. Hence, for a 30 year period the present costs of biofortification are $8-26m for each MN (CIAT/IFPRI 2004, personal communication from breeders). Juxtaposing these costs and the number of DALYs saved through biofortification indicate the cost-effectiveness in $/DALY.

Results

The current annual burden of ID in India is 4m DALYs lost, of which most are lost due to morbidity; another 2.8m healthy life years are lost due to ZnD but in this case most DALYs are lost due to mortality. Depending on the scenario used, biofortifying rice and wheat with iron could save 0.8-2.3m DALYs each year, which corresponds to a reduction of the burden of ID of 19-58%; biofortifying these crops with zinc could reduce the burden of ZnD by 20-38%.

The cost of saving one healthy life year through iron biofortification is $0.48-5.39 and with zinc-rich cereals a DALY can be saved for $1.04-7.34. These costs are far below the World Bank's threshold for health interventions of $150 per DALY saved (World Bank 1993) and still more favourable than those of other MN interventions, which fall into the range of 4.4-12.8 $/DALY (Gillespie 1998).

Conclusion

Using a refined DALY methodology to analyse health benefits of both iron-rich and zinc-rich rice and wheat, we found that these biofortified cereals can indeed reduce the burden of ID and ZnD in India substantially (by 20-60%). Thus, biofortification can help poor people to overcome malnutrition that impedes the development of their full physical and psychological potential.

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[2] Prevalence rates are stock figures, incidence rates are flow figures. Hence they can be derived from each other.

Scarce resources in budgets of donors and developing countries make their efficient allocation paramount. Following the World Bank (1993), interventions that cost less than $150 per DALY saved can be considered "highly cost-effective". And with DALY costs of $0.5-7.3, biofortification also outperforms alternative interventions. This indicates that developing both iron-rich and zinc-rich rice and wheat is a recommendable and efficient investment.

Yet, biofortification should not be considered a panacea for MN malnutrition – the long-term goal certainly remains to improve the overall diets of the poor and their livelihoods in general. However, being an agricultural approach and fully integrated into the food chain, biofortification could complement existing interventions like pharmaceutical supplementation and industrial fortification, which have their own strengths, but which tend to be more expensive and urban based. Hence, as part of a comprehensive strategy, biofortification holds the promise to be a valuable and viable contribution to combat MN malnutrition – if and as long as poor consumers and farmers (get to) eat these crops.

Apart from having shown the potential of biofortification for public health in India, this study also suggests that this approach should be considered in each country where ID or ZnD affect important sections of the population and where rice or wheat form the bulk of the popular diet. For this, because basic R&D costs are fixed and the germplasm of the biofortified crops is in the public domain (through the CGIAR centres), only costs for adaptive breeding and dissemination need to be incurred.

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