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Determinants of micronutrient nutrition and the potential role of novel, food-based strategies in diminishing corresponding malnutrition: an economic analysis

Research proposal

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1 Introduction

We will spare no effort to free our fellow men, women and children from the abject and dehumanizing conditions of extreme poverty, to which more than a billion of them are currently subjected. We are committed to making the right to development a reality for everyone and to freeing the entire human race from want.

(United Nations Millennium Declaration, 2000.)

In the United Nations Millennium Declaration the heads of State and Government have resolved “to halve, by the year 2015, the proportion of the world’s people whose income is less than one dollar a day and the proportion of people who suffer from hunger”. In the past, the Green Revolution contributed considerably to diminish hunger in the world: “One of the greatest achievements since the Second World War has been the phenomenal increase of research-based agricultural productivity that has fed millions and served as the basis of economic transformation in many poor countries” (Serageldin, 1999, p. 387). The adoption of high-yielding and faster growing crop varieties supported by irrigation “more than doubled cereal production in Asia between 1970 and 1995, while population increased by 60 percent. Instead of widespread famine, cereal and calorie availability per person increased by nearly 30 percent, and wheat and rice became cheaper” (IFPRI, 2002, pp. 3/4). And with regard to the environmental consequences Borlaug (2000, p. 5) states: “Had the global cereal yields of 1950 still prevailed in 1999, we would have needed nearly 1.8 billion ha of additional land of the same quality – instead of the 600 million that was used – to equal the current global harvest […] if more environmentally fragile land had been brought into agricultural production, think of the impact on soil erosion, loss of forests and grasslands, biodiversity and extinction of wildlife species that would have ensued.”

Acknowledging these achievements of the Green Revolution, and not to enter a general discussion about its drawbacks, time and progress in nutritional sciences have revealed one shortcoming of the Green Revolution: the main focus of the Green Revolution were yields, i.e. the Green Revolution concentrated on quantity only. Higher yields lead to lower food prices and cheaper food resulted in an increased caloric intake (Evenson and Gollin 2003). Since the early 1960s, however, the focus of nutritionists has widened and the role of micronutrients[1] in human nutrition gets more attention. It has become clear that humans require not only macronutrients but also micronutrients in order to maintain optimal health (DellaPenna 1999). Accordingly, in its 4th Report on the World Nutrition Situation the Administrative Committee on Coordination Sub-Committee on Nutrition (ACC/SCN) of the United Nations dedicates a whole chapter to micronutrients and micronutrient deficiencies and estimates more than 3.5 billion people in the developing world to be affected by iron deficiency, 2 billion people to be at risk of dietary iodine deficiency and 3 million preschool children to suffer from clinical vitamin A deficiency (VAD). Given that the world's population just tops 6 billion people, these are huge numbers. As these deficiencies imply staggering costs with regard to lives lost, foregone economic growth and poor quality of life, new technologies and approaches are needed to help address this problem (CIAT/IFPRI 2002). As it has already done in the Green Revolution, agriculture can have a role to play in reducing this newly recognised problem of malnutrition by developing more micronutrient-dense staple crops (Underwood 1999).

Of course, as Bouis (2002, pp. 352) puts very well: "We all envision a future when nutrition education and increased incomes of the poor will be combined with greater availability and lower food prices to improve dietary quality." But he is just as right when he continues: "However, this will require the eventual investment of many billions of dollars by small farmers, the business sector, and governments over several decades to increase the production and availability of these nutrient-rich, nonstaple foods. In the meantime, specific agricultural strategies can be implemented to improve nutritional status. One of these is 'biofortification' – breeding for micronutrient-dense staple food crops, a strategy of getting plants to fortify themselves." Because even if in the long-term a solution to deficiencies like iron deficiency anaemia consists in more diverse diets, fortification can have a more immediate effect (Hunt 2002). This is an approach that has already proven to be successful in developed countries, where it reduced iron deficiency during the latter half of the 20th century (Ramakrishnan and Yip 2002).

[1] "Micronutrients are those vitamins and minerals needed in small amounts to support physiological functions that must be provided in foods or as supplements because they cannot be made by the body in amounts sufficient to meet needs." (Underwood, 1999, pp. 3/4.)

To understand the underlying mechanisms influencing micronutrient malnutrition and to be able to assess any intervention addressing this problem it is paramount to be aware of the food consumption patterns of the people concerned. Knowledge of the potential determinants of the consumption of micronutrients (like household incomes, food prices, parental education and their nutritional knowledge, as well as culturally-based customs and corresponding food preferences) can provide crucial information for designing policies and intervention programmes to improve human nutrition (Bouis and Novenario-Reese 1997). With regard to food consumption patterns it is especially the role income plays in improving nutrition that is of interest. Once the pressing need to satisfy basic energy requirements is met, i.e. acute hunger is satisfied, it is not assured that higher incomes necessarily lead to better and more wholesome nutrition (Behrman 1995). People do not feel the lack of micronutrients the way they feel the lack of calories, i.e. they do not feel hungry if they experience a micronutrient deficiency – thence the expression "hidden hunger". Therefore micronutrient deficiencies are not only or necessarily limited to the poor or to developing countries: iron deficiency amongst pregnant women in industrialised countries, for instance, is a matter of concern (Makrides et al., 2003) and there are whole sub-groups within the societies of industrialised countries that are at real risk to be affected by micronutrient malnutrition like, for instance, iron deficiency (Cogswell et al. 2003). For the USA the Centers for Disease Control and Prevention (2002) have estimated that the prevalence of iron deficiency is about two times higher among non-Hispanic black and Mexican-American females than among non-Hispanic white females. And for some nutrients larger groups of older Americans consume less than one third of the recommended dietary allowance (Wakimoto and Block 2001). Moreover the World Health Organisation (WHO 2003), points out that in high-income as well as in low-income countries highly processed but micronutrient-poor foods replace traditional food that tends to be richer in micronutrients.

Given this context our intention is to analyse the underlying determinants of micronutrient malnutrition and subsequently to assess, from an economic point of view, the potential role of new seed technologies in decreasing this burden of mankind. To this end it is proposed to analyse the food consumption patterns across three countries in different affected regions of the world. This will be done with regard to three micronutrients, namely iron, zinc and vitamin A, which are the three target micronutrients in the "Biofortification Challenge Programme" of the International Centre for Tropical Agriculture and the International Food Policy Research Institute (CIAT/IFPRI, 2002). To do so in the second chapter the availability of these micronutrients in people's diets will be estimated for the population of corresponding surveys in the target countries by following standard econometric procedures. Subsequently two ex-ante cases studies will be conducted to establish the cost-effectiveness of food-based strategies that aim at diminishing micronutrient malnutrition. The objective is to clarify whether biofortification is an economically viable approach to improve, in the end, human health and well-being. To do so the studies have to overcome the ethical hurdle of assessing costs and benefits with regard to human life. In this context the approach of "disability adjusted life years" (DALYs) will be applied, thus following the methodology that was adopted by Zimmermann and Qaim (2002) for the first time in such a context.

2 Determinants of the dietary availability of micronutrients

2.1 Do people demand micronutrients?

In this chapter of the study the interest is to find out what determines the dietary availability of micronutrients. That is, this chapter asks for the implied "demand" for micronutrients. The demand is implied because in general people do not demand particular nutrients, people demand food:

> "Household demand for micronutrients is likely to reflect not that micronutrients are choice variables that appear directly in the household objective function, but that micronutrients have indirect effects through choice variables that do appear in the objective function or simply are characteristics of multidimensional goods (foods) that enter directly into the household objective function." (Behrman, 1995, p. 12).

It appears reasonable that people who get food in sufficient quantities and with adequate variation should eventually cover their micronutrient requirements. Yet, this is by no means ensured, as is shown by iodination of salt and fluoridation of drinking water in several industrialised countries where, in general, quantity and diversity of food is no problem. This outcome is possible because food demand is influenced by several preferences and if the utility derived from food is not influenced by any preference for micronutrients the resulting dietary availability of micronutrients in the diet is fortuitous, i.e. it depends on whether the food people happen to prefer happens to be rich in micro-nutrients or not (Bouis, 1996). Thus if the interest is to combat micronutrient malnutrition it becomes imperative to understand the underlying determinants of the consumption of micronutrients and their magnitudes of response (Behrman, 1995). A general function for looking at the dietary availability of micronutrients would look like the following:

DAM = f (I, P, Q, S, R)

Where:
DAM = dietary availability of micronutrients
I = income
P = food prices
Q = food quality and food characteristics
S = socio-economic, demographic and educational characteristics
R = regional determinants

As pointed out above, the first idea that might come to mind if one talks about fighting malnutrition is to make people richer so they can afford more and better food. With regard to energy undernutrition and calorie intake this rationale is, for instance, discussed by Ravallion (1990) and by Behrman and Deolalikar (1989), where the importance of food variety vs. calorie content is underlined. In the case of micronutrients there might be a clash between what people deem to be better food, given their set of preferences, and what nutritionists deem to be better food (Brunsø et al., 2002). As people do not notice if their diet is deficient in one micronutrient or another, it cannot be taken for granted that people who could afford a more nutritious diet actually buy the food they need. That is, making people richer might not be the best means to increase the availability of micronutrients to deficient people; even though there is no doubt that making people richer is a valid, desirable and important concern in its own right.

Closely connected with people's ability to afford more and better food is the issue of dietary diversity. In a way dietary diversity provides a safeguard against one-sided and unbalanced nutrition that might lack essential components people are not aware of (Johns 2003). Thus, dietary diversity is seen as a way of ensuring nutrient adequacy (Ruel 2002). Grivetti and Ogle (2000) underline the importance of a diverse diet, too. However, they see dietary diversity less as a consequence of higher incomes but rather as a consequence of indigenous and traditional knowledge of edible wild plants and traditional species. In both cases, however, the assumption is that dietary diversity has a positive impact on the dietary availability of micronutrients.

In above paragraph, traditional knowledge of edible species is expected to have a positive impact on the dietary availability of micronutrients. Another, complementary approach to increase the availability of micronutrients might be formal education and the dissemination of nutrition information. It is reasonable to assume that people who are knowledgeable about the importance of balanced diets endeavour to have balanced diets. However, Wolfe and Behrman (1983) see the possible impact of (women's) education on nutrition inconclusive a priori, when they contrast efficiency effects in household production from possibly counteracting taste effects. Therefore educating people, just as making people richer, is a valuable concern, but the contribution of education to the eventual availability of micronutrients to people is an open question, too.

As was explained in the preceding paragraph, education of people might interfere with taste. Therefore tastes, customs and traditions with regard to nutrition determine micronutrient consumption, too. Thus informing people about more nutritious food and alternative diets is a precondition of changing their eating habits. But the success of this undertaking hinges on the strength of counteracting preferences. “People […] are not likely to change their micronutrient consumption choices unless they perceive that such changes improve their welfare” (Behrman, 1995, p. 8). But tastes and customs might also be changing for other reasons: Huang and Bouis (1996) point out that structural shifts might occur due to urbanisation or due to generational differences in tastes.

Logistics respectively location is another issue: especially fruits and vegetables that spoil easily might only be available locally or regionally. If these fruits or vegetables are important suppliers of a particular micronutrient, dietary availability of this micronutrient is bound to be more favourable in the region than elsewhere. It is also likely that homegardens are more common in rural areas. These might increase the availability of food and help to avoid malnutrition (Dharmasena and Wijeratne 1996). This, in turn, could signify that the urban population is at a disadvantage. However, as Wolfe and Behrman (1983) point out, another factor is refrigeration, which might be more widespread in urban areas. It might also be true that the urban population has access to a wider variety of foodstuffs and, hence, can eat a more balanced diet while the diet of the rural population is more monotonous. In this case the urban population would be at an advantage.

Non-market consumption opportunities are another possible determinant of micronutrient consumption: if the household receives food in kind, for example as a donation or as (irregular) part of remuneration, it might perceive the food more as a windfall gain and partly consume it in addition to the food it normally consumes. Thus, if the household receives foodstuffs that are rich in micronutrients this might have a considerable impact on the dietary availability of micronutrients.

Another factor that could influence consumption of micronutrients is changes in the prices of different foodstuffs. Most foodstuffs or food groups are, to some extent, substitutes of each other. Therefore, if micronutrient-rich food becomes cheaper, microeconomic theory tells us that demand for this food will increase, while demand for the relatively more expensive alternative will decrease. As is pointed out in the “Biofortification Challenge Programme” of CIAT/IFPRI (2002), the Green Revolution’s focus on staple cereal crops led to substantial price decreases for this food group. At the same time, however, nutritionally valuable fruits, vegetables and pulses became relatively more expensive and their consumption declined. In this framework price increases of relatively micronutrient-rich foodstuffs lead to decreases in the dietary availability of micronutrients.

With regard to the **dietary** availability of micronutrients, there might also be scale effects: if, for instance, wastage in bigger households is less pronounced the deducted dietary availability of micronutrients decreases. On the other hand more household members, through their different tastes and preferences might increase dietary diversity, in which case household size might work in the opposite direction.

In the context of ensuring adequate diets, there might also be a gender issue: women might be more likely to look after proper nutrition of their families than men. Another social issue might be the ethnicity of the heads of household. As mentioned above, Grivetti and Ogle (2000) state that indigenous knowledge about edible wild plants can contribute to an improved supply of micronutrients. This goes along with the possible impact of tastes, customs and traditions, which might vary amongst different ethnicities. On the other hand ethnicity and language barriers might exclude some parts of a population from the dissemination of nutritional information.

2.2 Methodology

2.2.1 Econometric model

To analyse the determinants of the dietary availability of micronutrients, this study takes a quantitative approach. The original model $DM = f\,(I, P, Q, S, R)$ then takes the form:

$$\ln DAM = \alpha + \beta_i \ln I + \beta_p \ln P + \beta_q Q + \beta_s S + \beta_r R + \varepsilon$$

with the variables

DAM = dietary availability of micronutrients
I = income
P = food prices
Q = food quality and food characteristics
S = socio-economic, demographic and educational characteristics
R = regional determinants

and the coefficients

α = intercept/constant term
β_i = coefficient of variable I
ε = disturbance/error term

For analysing the dietary availability of micronutrients we will apply a two-stage least squares regression in which the income variable (approximated by total expenditure) is instrumentalised. This is necessary because there exists a problem of simultaneity: income is not only likely to influence the dietary availability of micronutrients, but consumption of micronutrients is also expected to have an impact on income, as Weinberger (2003) finds when testing the Efficiency Wage Hypothesis for iron intake and labour productivity.

2.2.2 Origin of data

The data used in this study comes from the Living Standard Measurement Study (LSMS) surveys that are supported by the World Bank. The LSMS was established "to explore ways of improving the type and quality of household data collected […]. The objectives of the LSMS were to develop new methods for monitoring progress in raising levels of living, [and] to identify the consequences for households of current and proposed government policies" (Grosh and Glewwe, 1995, p. 1).[2] A LSMS survey is characterised by a multi-topic questionnaire and extensive quality control.

The advantage of these data sets is that each survey follows a prototype with roughly similar structures and standards. Moreover, data sets are available for different countries of different regions of world at different points in time. Given the scope of this study it would be impossible to obtain such data as a primary source. Apart from availability and coverage, another advantage of the LSMS data sets is their substantial sample sizes and the expected small degree of measurement errors.

These surveys were not specifically conducted with nutrition issues in mind. Therefore, on the basis of the data available, no statements can be made about the **bioavailability** of micronutrients, i.e. about the net amount of micronutrients that can be absorbed by the body. All conclusions drawn from these data-sets can only establish determinants for the

[2] The following information about the LSMS will draw heavily, if not exclusively, from this source, which is also referred to at the LSMS web site of the World Bank (http://www.worldbank.org/lsms/).

nutritional availability of micronutrients, i.e. the gross amount of micronutrients that are available prior to cooking of the food and prior to the potentially deteriorating impacts of parasites or diseases and to the impacts of inhibitors and enhancers in the food once the food is eaten. Yet, nutritional availability is the first link in the chain of micronutrient deficiencies and it lies at the heart of interventions like nutritional education, food fortification and dietary supplementation. As such, looking at nutritional availability is a good starting point for this study.

However, a drawback of these data-sets is the fact that the LSMS-surveys do not register **individual food consumption** data, i.e. the actual intake of foodstuffs by the individuals. LSMS surveys rather record recalls of food expenditures for different foodstuffs over longer periods of time. Potentially crucial issues like the intra-household distribution of food and of specific micronutrient-rich foodstuffs cannot be clarified either. All results on the level of individuals drawn from these data-sets are only inferences that are based on calculations with the number of adult equivalents or **average eaters** (AEs) in the households, where one adult equivalent is calculated on the basis of average energy requirements of an adult man and an adult woman.[3] Moreover there is the problem of food the household bought but subsequently threw away, fed to guests or animals or gave away. In these cases the food entered the computation of the nutritional availability of micronutrients without being available to the household members at all. This possibility might lead to results that are biased towards richer households: poorer households are less likely to throw away food or to give it away. To the contrary, it is reasonable to assume that poorer households are the beneficiaries of inter-household transfers of food; even if the surveys also record non-market transfers of food, some transfers are bound to go unaccounted for. Altogether it seems likely that the computations of the nutritional availability of micronutrients to the members of richer households are upwardly biased. With regard to measuring the availability of calories, these problems are exposed in Bouis and Haddad (1992).

[3] Therefore an adult man equals more than one AE, while an adult woman is equals less than one AE. Children of different ages and gender are, again, represented by different fractions of one AE, according to their relative energy requirements.

2.3 Determinants of micronutrient consumption in Nicaragua

2.3.1 Country-specific data-set and variables used

As an example for dietary availability of micronutrients in Central America we first look at the consumption of iron in Nicaragua, a country with a total population of 4.8 million inhabitants and a gross national income (GNI) per capita of 370 US$ in 1998[4]. According to OMNI (1998) vitamin A and iron deficiencies represent public health problems in Nicaragua in 1993, with the prevalence rate of vitamin A deficiency (VAD) being the second highest in Central America and the Caribbean and with iron deficiency anaemia (IDA) occurring in 30-50 percent of young children and women. A little bit later, in 1998, an LSMS survey was conducted in Nicaragua with a sample size of 4.200 households.

With regard to our interest in the dietary availability of micronutrients the relevant section of the questionnaire was the expenditure survey for the last fortnight on food, beverages and tobacco (section 9 part A "Gastos en alimentos, bebidas, tabaco en los últimos 15 días"). The information from this section allowed establishing prices and quantities for 60 different foodstuffs. With this information it was possible to use food composition tables[5] to compute the dietary availability of micronutrients for each household.

From the total micronutrient content of all foodstuffs in a household, the dietary availability of micronutrients was calculated per average eater per day and used as the dependent variable. The other, independent variables were more straightforward and, with some minor transformations like re-coding or aggregation of dummies, could be taken from the data-set. These independent variables represent the determinants of dietary availability of micronutrients, as discussed in chapter 2.1, and were people's total expenditure (as proxy for income), food variety, household size, food prices, people's education and nutritional knowledge, gender and ethnicity, agricultural activities, non-market consumption opportunities and regional and rural-urban differences.

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[4] Atlas method (current US$). Source: World Development Indicators database, via http://devdata.worldbank.org/data-query/

[5] The food composition tables used were: 1) FAO / LATINFOODS (2002). "Tabla de Composición de Alimentos de América Latina" at www.rlc.fao.org/bases/alimento, 2) U.S. Department of Agriculture, Agricultural Research Service (2002). USDA Nutrient Database for Standard Reference, Release 15, at www.nal.usda.gov/fnic/foodcomp, and 3) Universität Hohenheim, Institut für Biologische Chemie und Ernährungswissenschaft, at www.uni-hohenheim.de/~wwwin140/INFO/LM/lmgrup.htm.

2.3.2 Food expenditure and dietary iron availability per food group

To get a quick overview over the structure of the food consumption of different income groups in Nicaragua, Table 2-1 provides daily expenditures in Córdobas (C$) for the most important foodstuffs and food groups, and their share in total daily food expenditure per adult equivalent and grouped by income quintiles.

Table 2-1: Daily expenditure on food per adult equivalent and expenditure shares

	Quintile 1		**Quintile 2**		**Quintile 3**		**Quintile 4**		**Quintile 5**	
Food	***C$***	***%***	***C$***	***%***	***C$***	***%***	***C$***	***%***	***C$***	***%***
Rice	0.57	14	0.86	13	1.04	11	1.21	10	1.40	7
Corn	0.39	10	0.44	6	0.36	4	0.29	2	0.20	1
Tortilla	0.43	11	0.61	9	0.58	6	0.69	6	0.79	4
Bread & pasta	0.15	4	0.32	5	0.55	6	0.70	6	1.17	6
Beans	0.42	10	0.83	12	0.87	9	0.93	8	0.96	5
Roots & tubers	0.07	2	0.11	2	0.15	2	0.22	2	0.35	2
Vegetables	0.13	3	0.32	5	0.47	5	0.73	6	1.33	7
Plantains	0.11	3	0.13	2	0.22	2	0.28	2	0.40	2
Fruits	0.05	1	0.10	1	0.18	2	0.35	3	0.75	4
Meat & fish	0.16	4	0.48	7	0.99	11	1.77	15	3.98	20
Eggs	0.15	4	0.32	5	0.33	4	0.51	4	0.57	3
Milk	0.22	6	0.39	6	0.42	5	0.55	5	0.82	4
Other foods & drinks	1.19	30	1.87	28	3.08	33	3.99	33	6.93	35
Total of all foods	4.04	100	6.77	100	9.24	100	12.22	100	19.63	100
Annual expenditure per capita (C$)	1,714		3,014		4,426		6,545		16,604	

Source: World Bank, Nicaragua Living Standards Measurement Study survey, 1998

People in the poorest quintile spend half their food budget on staples (cereals and beans) and derive two thirds of their energy from this source. In the richest quintile still half of all calories come from these staples, but only one fourth of the food budget is spent on them. Overall it can be stated that richer households consume absolutely more of everything, but relatively less of cereals, especially corn and tortilla, which are relatively rich in micronutrients. However, richer households consume absolutely more vegetables, fruits and meat & fish, which are richer sources of micronutrients; expenditure shares of meat & fish quintuple between the poorest and the richest quintile.

Given the minimum calorie requirement of 2,613 kcal per adult equivalent, only C$ 2 spent on corn would buy enough calories to satisfy the minimum energy requirement. With an average daily food budget of C$ 4 in the poorest quintile there is, thus, still scope to improve nutrition beyond meeting the most pressing energy needs.

Table 2-2: Deducted availability of iron per adult equivalent and shares per day

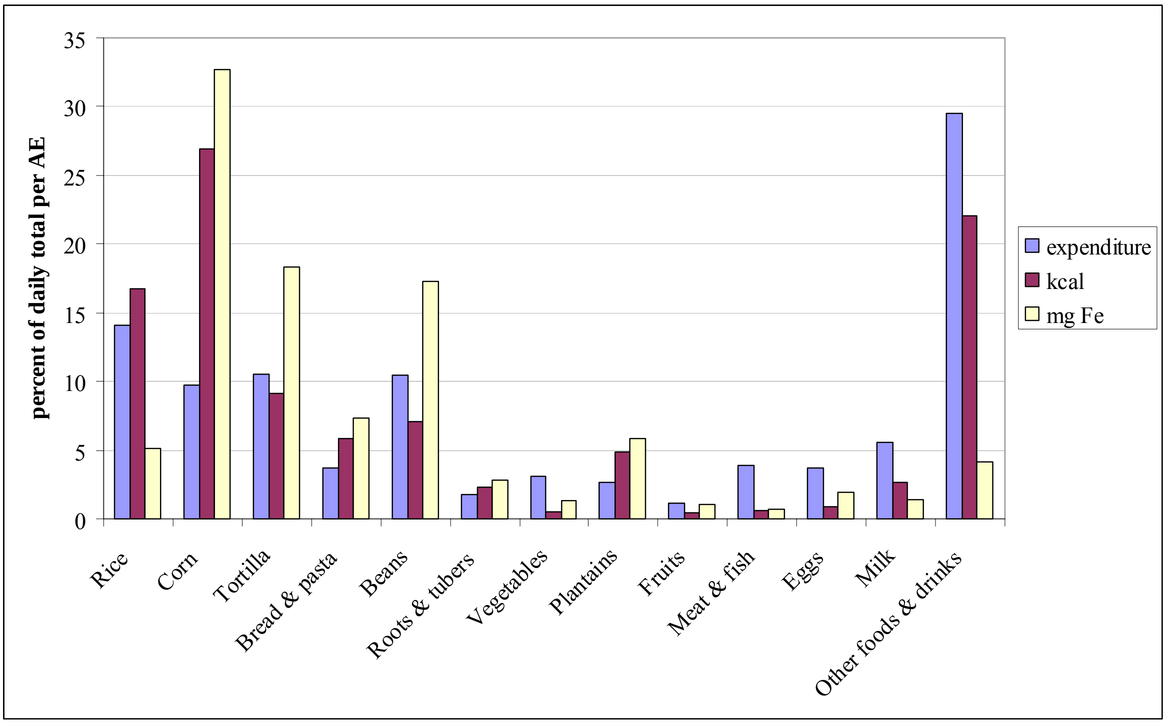
Food	Quintile 1 *mg Fe*	*%*	Quintile 2 *mg Fe*	*%*	Quintile 3 *mg Fe*	*%*	Quintile 4 *mg Fe*	*%*	Quintile 5 *mg Fe*	*%*
Rice	0.63	5	0.91	5	1.08	6	1.18	5	1.28	5
Corn	3.96	33	4.16	23	3.23	17	2.61	12	1.75	6
Tortilla	2.23	18	2.85	15	2.64	14	3.25	14	3.53	13
Bread & pasta	0.89	7	2.28	12	3.49	18	4.02	18	5.87	21
Beans	2.09	17	3.98	22	4.02	21	3.93	17	4.40	16
Roots & tubers	0.34	3	0.36	2	0.45	2	0.59	3	0.73	3
Vegetables	0.16	1	0.45	2	0.55	3	0.90	4	1.42	5
Plantains	0.70	6	0.92	5	1.04	5	1.17	5	1.21	4
Fruits	0.12	1	0.15	1	0.27	1	0.61	3	0.90	3
Meat & fish	0.09	1	0.26	1	0.55	3	1.00	4	2.21	8
of which haeme iron	*0.03*	*0*	*0.10*	*1*	*0.22*	*1*	*0.40*	*2*	*0.88*	*3*
Eggs	0.23	2	0.56	3	0.54	3	0.75	3	0.86	3
Milk	0.18	1	0.31	2	0.29	2	0.39	2	0.45	2
Other foods & drinks	0.50	4	1.22	7	1.31	7	2.26	10	3.31	12
Total of all foods	12.11	100	18.41	100	19.46	100	22.65	100	27.93	100

Source: World Bank, Nicaragua Living Standards Measurement Study survey, 1998

Table 2-2 table looks at the daily dietary availability of iron per adult equivalent per quintile. As can be seen from the table, corn is the major supplier of iron for the poor. Together with tortillas, which consist of corn, 50 percent of the iron that is available to the poor comes from corn only, and 80 percent comes from all staples together. The richer households' preference for rice, which contains only very little iron, and the associated low dietary availability of iron is, however, overcompensated through increased dietary availability of iron from bread & pasta, vegetables and meat & fish. Yet, 60 percent of the iron that is available to the richest households still comes from staples. In the end there is 2.3 times as much iron available to an adult equivalent in the top quintile as compared to the iron that is available to an adult equivalent in the lowest quintile.

Figure 2-1 summarises the preceding tables for the poorest quintile. It confirms that corn is by far the cheapest provider of both energy and iron, while bread & pasta, roots & tubers and plantains also have a favourable price-performance ratio of money spent on the food and energy and iron derived from it. Beans are also a relatively cheap provider of iron. In the case of rice, however, a relatively big share of daily food expenditure is spent to obtain only a relatively small amount of the daily iron supply. Only 2.5 Córdobas spent on corn buy 25 mg iron, which is the dietary iron requirement for non-pregnant women who consume diets with a low bioavailability of iron. A corn-only-diet is certainly not desirable, but it gives an idea of the range of manoeuvre the poorest households have, with their food budget of C$ 4 per adult equivalent.

Figure 2-1: Relationship between expenditure on food and the supply of energy and iron derived from food for the poorest quintile (values per AE per day)



If it is assumed that each household member receives a share of the same food in accordance with his or her energy requirements, i.e. if the rationale for calculating the adult equivalents is fulfilled, then the total iron content of these food shares can be deducted. This total amount of iron can be compared to dietary iron requirements, as established by the Food and Agricultural Organisation (FAO, 1988). If this is done, it can be shown that in the poorest quintile no age and gender group obtains enough iron to meet the requirements, while in the richest quintile only the groups of adolescent girls and, especially, pregnant women fail to meet their requirements.

2.3.3 Estimation of a function of the dietary availability of iron

With the variables that could be taken from the LSMS data-set or that could be generated from it, for the case of Nicaragua the equation of chapter 2.2.1 contains the variables that are reported in Table 2-3. The result of the estimation of the dietary availability of iron in Nicaragua within the LSMS population is then provided in Table 2-4 and will be discussed subsequently.

Table 2-3: Variables used in the estimation of the dietary availability of iron

Variables	Mean	SD
Dietary iron that is available per AE per day (mg)	21.520	20.26
Total annual expenditure per capita (C$)	6889.899	9133.332
Household size in AEs	4.673	2.32
Food variety (number of foodstuffs consumed)	16.587	9.329
Price of corn (C$/kg)	5.439	11.704
Price of tortilla (C$/kg)	7.139	10.613
Price of rice (C$/kg)	7.323	3.058
Price of bread (C$/kg)	9.518	25.106
Price of beans (C$/kg)	12.575	6.860
Price of roots & tubers (C$/kg)	5.433	6.618
Price of vegetables (C$/kg)	12.607	44.083
Price of fruits (C$/kg)	14.496	52.336
Price of meat & fish (C$/kg)	21.814	13.812
HH consumed food that could not be accounted for (yes = 1)	0.453	0.498
HH obtained iron-rich food in kind (yes = 1)	0.657	0.475
Age of the head of HH	45.418	15.739
Female head of HH (yes = 1)	0.261	0.439
Mother tongue of the male part of heads of HH is indigenous (yes = 1)	0.018	0.131
Mother tongue of the female part of heads of HH is indigenous (yes = 1)	0.021	0.145
Male part of heads of HH is literate (yes = 1)	0.540	0.498
Female part of heads of HH is literate (yes = 1)	0.616	0.486
Cases of diarrhoea in HH over the last month	0.244	0.569
Agricultural activity of a HH member (yes = 1)	0.365	0.481
Backyard production of the HH (yes = 1)	0.313	0.464
HH is located in the Atlantic region (yes = 1)	0.165	0.371
HH is located in the Central region (yes = 1)	0.351	0.477
HH is located in the Pacific region (yes = 1)	0.355	0.479
Urban household (yes = 1)	0.539	0.499

The model explains about one third of the dietary availability of iron and most of the signs of the coefficients are also basically in line with what could be expected, while most of the less expected outcomes are not significant. With regard to income, total expenditure is highly significant and shows the expected positive sign, i.e. an increase in total expenditure leads to an increased supply of dietary iron. The coefficient implies an elasticity with regard to the dietary availability of iron of 0.15, which means that every percent increase in expenditure will increase the daily iron supply per average eater by 0.15 percent. This result is lower than the 0.27 income elasticity reported by Bouis and Novenario-Reese (1997) for iron intake in households in rural Bangladesh, but considerably higher than the implied income elasticity of 0.01 for iron reported by Wolfe and Behrman (1983) for households in Managua (Nicaragua). The coefficient for household size is also highly significant. Its negative sign means that the addition of an average eater to the household leads to a decrease in the supply of dietary iron for each average eater in the household. Ward and Sanders (1980) found a similar effect in the Brazilian Northeast and Wolfe and Behrman (1983) for Managua. Because we look at induced dietary availability of iron only, this could be explained through economies of scale: bigger households might experience less loss of food with the individual members of the household still eating as much as members of smaller households.

Table 2-4: Results of the regression on the nutritional availability of iron

Variables	Coefficient		t-statistic
Total expenditure (ln)	0.1508	***	2.81
Household size in AEs	-0.0774	***	-10.32
Food variety (ln)	0.3359	***	10.48
Price of corn (ln)	-0.0766	***	-3.65
Price of tortilla (ln)	-0.2226	***	-8.30
Price of rice (ln)	-0.0334		-1.15
Price of bread (ln)	-0.1611	***	-10.59
Price of beans (ln)	-0.1360	***	-4.60
Price of roots & tubers (ln)	0.0119		0.61
Price of vegetables (ln)	-0.1103	***	-11.26
Price of fruits (ln)	-0.0204	**	-2.11
Price of meat & fish (ln)	-0.1841	***	-7.08
Unaccounted food	-0.0315	*	-1.69
Food in kind	0.2170	***	9.78
Age of the head of HH	0.0006		0.79
Female head of HH	-0.0173		-0.66
Heads of HH:			
Non-Spanish speaking male	-0.1601		-1.45
Non-Spanish speaking female	-0.2565	**	-2.54
Literate male	-0.0108		-0.44
Literate female	-0.0150		-0.68
Diarrhoea in HH	-0.0030		-0.17
Agricultural activity	0.1241	***	4.43
Backyard production	-0.0381		-1.59
Atlantic region	0.3266	***	8.26
Central region	0.2378	***	6.57
Pacific region	0.0067		0.17
Urban household	-0.0432		-1.54
Intercept	-0.2679		-0.52
Number of observations	3991		
F (27, 3963)	69.53	***	
Adjusted R-squared	0.3629		

Significance levels: 99% = ***, 95% = **, 90% = *

The positive and highly significant result for food variety confirms the usefulness of using dietary diversity as indicator for a balanced diet. The impacts of the prices of the different foodstuffs goes confirm with expectations, too. The coefficient of the price of corn is very significant, even though the price response is not very elastic. This comes at no surprise because corn is the main staple in the Nicaraguan diet. Still, if the price of corn rises, this implies that some substitution will take place. As corn is relatively rich in iron, any substitute is likely to be less iron-rich, hence the negative sign of the coefficient. In turn, the response to price changes of tortilla is relatively elastic, as tortilla is a more processed foodstuff and more easily substituted by corn, rice, pasta or bread. The results for the other foodstuffs go along these lines, with those foodstuffs being not significant or not having a bigger impact that are either poor in iron or that play no major role in Nicaraguan diets.

Food that could not be accounted for also has a significant impact on the consumption of iron: if food is eaten that could not be accounted for in the survey questionnaire, there is less iron that could enter the computed dietary availability of iron. This rationale is supported by the negative coefficient of the dummy variable. Food in kind works in the other direction. If a household obtains food through non-market means, iron consumption is increased. This might be because this food replaces less iron-rich food, or because it is simply eaten in addition to the usual diet.

The different socio-economic and educational variables are not significant, except for the case where there is an indigenous female amongst the heads of household. The significance of this coefficient might be explained by differences in taste and dietary customs among indigenous and primarily Spanish-speaking population groups. However, it might also be that cultural and language barriers hinder extension of nutrition information to indigenous housewives.

The remaining variables all relate, in some way, to the location of the household. Different regions and proximity to agricultural activities are all significant. Involvement in agricultural activity seems to warrant better supply of iron-rich foods or more abundant supply of food in general. It is also possible, however, that people involved in agriculture perform more heavy physical activities and, therefore, just eat more food in general, thence increasing the overall supply of nutrients. The significance of regional variables might also be explained by different tastes and dietary customs or by regional availability of food.

2.3.4 Preliminary conclusions

The equation of the determinants of iron consumption was estimated and analysed for the population of an LSMS survey in Nicaragua in 1998. The main findings were that total expenditure, household size, variety of the food eaten, prices of foodstuffs (especially of iron-rich staples), receipt of iron-rich food in kind, presence of an indigenous female amongst the heads of a household, involvement in agricultural activity, and regional location of a household are the major determinants for the consumption of iron.

To improve the supply of dietary iron to an average eater and, thus combat iron deficiency in Nicaragua one way is, obviously, to eradicate poverty and increase incomes across society. This is, however, a long-term objective and no practical means to improve people's nutrition in a shorter period of time. Another way to increase the consumption of iron could be to disseminate nutritional information and to promote dietary diversity. Yet, this requires people to change their tastes and traditions. The result of such interventions hinges on people's preferences, and such changes might take their time, too.

In kind distribution of iron-rich foodstuffs could be another way of improving iron consumption, but this seems only be feasible on smaller scales and is probably not very sustainable. On the other hand, with regard to the prices of iron-rich foodstuffs there is little that can be done under free market conditions. One solution could thus be to just increase the iron content of iron-poor foodstuffs (or to increase the iron-content of iron-rich foodstuffs even further), which could be achieved through fortification. In the case of Nicaragua the most widely eaten staple, especially amongst the poor, is corn. Therefore fortifying corn would be the most promising means to improve iron consumption and the well-being of people in Nicaragua also in the short run.

In the study following this proposal more countries will be analysed and results for Nicaragua will be contrasted with the determinants of the dietary availability of iron in these countries before a final conclusion will be drawn.

3 Costs and benefits of new seed technologies in human nutrition

In the preceding chapter determinants for the dietary availability of micronutrients were analysed. One way of improving the nutritional and health status of the poor in developing countries is, thus, to initiate policies to "steer" these determinants and, as a consequence, improve the dietary supply of micronutrients. However, this can be a difficult long-term undertaking; for instance a general and sustained increase of the income of the poor is on the agenda of the international development community since decades but poverty is still wide spread. A more direct and rapid solution, as was pointed out too, is to directly increase the micronutrient content in the food. If this is done through conventional breeding or through genetic engineering this can also be called "biofortification". Yet, the question remains whether such an approach can be justified from an economic point of view.

To assess costs and benefits of biofortification implies assessing costs and benefits with regard to human nutrition and health. This raises an ethical issue because ultimately human life and well-being enters the calculation, thus creating a methodological hurdle. When assessing costs and benefits of normal crops, the analysis is rather straightforward: monetary benefits of higher yields or quality improvements (i.e. benefits to accrue to the producer) are contrasted with the costs of research and development. In this case the peasants are aware of the advantage they might take of new seeds and the companies can calculate their expected returns, i.e. a simple market model applies. In the case of nutritional and health benefits to the poor, the poor – as consumers – are not very likely to be aware of the benefits they will derive from micronutrient-enriched food in comparison to conventional food. And even if they are, they might not be able to create the demand that is necessary to send the corresponding signals in a market setting; they might be willing to pay for more nutritious food but lack the financial means to do so.

The methodological problem of conducting a cost-benefit analysis when human life and well being in a non-market setting is involved will be discussed in the following subchapter. Later on this methodology is supposed to be applied to case studies to complete the research for my dissertation proposed here.

3.1 Methodology to analyse costs and efficiency of biofortified crops

Zimmermann and Qaim (2002), on whose study the chapter in this proposal draws heavily, conducted a cost-benefit analysis for the case of rice that is enriched with vitamin A, so called “Golden Rice”. To do so they used the approach of disability-adjusted life years (DALYs), which measure the quality and length of life. Under this approach benefits are expressed in DALYs saved, while costs are expressed in monetary terms. This way different health initiatives can be compared – and ranked according to the cost of one DALY saved. In doing so the tricky issue of putting a monetary value to life is circumvented while policy recommendations are still possible. If policy makers are able to attach a precise value to life, then the DALY approach can also stand alone, i.e. in this case benefits and costs can be expressed in monetary terms and standard measures of profitability, like the internal rate of return, can be used.

Micronutrient deficiencies increase morbidity and mortality. Introduction of a fortified staple crop, which reduces the micronutrient deficiency, will decrease this burden of affected populations. However, this depends on the actual effectiveness of the fortified target crop, i.e. issues of bioavailability of the micronutrient to the human body and acceptance of the crop by producers and consumers have to be clarified. If this effectiveness is established, the benefits of the introduction of a fortified staple crop can be determined. To do so it is also necessary to calculate the outcome of the counterfactual situation, i.e. it is necessary to extrapolate a result for the case the present situation is unchanged.

In their study Zimmermann and Qaim (2002) base their approach on the DALY approach as it was used by Murray and Lopez in their estimation of the "global burden of disease", and as it was subsequently used by the WHO and by the World Bank. It is this approach that we intend to apply in our case studies. The corresponding formula is the following:

$$DALYs_{lost} = YLL + YLD_{temp} + YLD_{perm}$$

where YLL are (healthy) years of life lost, YLD_{temp} are years of life lived with temporal disability and YLD_{perm} are years of life lived with permanent disability. In turn YLL is the sum of all people considered multiplied by the mortality rate associated with the micronutrient deficiency and YLD is the sum of all people considered times the incidence rate of the disabilities due to the micronutrient deficiency times corresponding disability weights. In the case of YLL and YLD_{perm} the remaining life expectancy is being discounted at a specified rate, while in the case of YLD_{temp} only the duration of the temporary disease is considered:

YLL = f (population, mortality rate of disease)
YLD = f (population, incidence rate of disease, disability weights, discount rate)

The DALYs lost due to micronutrient deficiency have to be established for the situation where a biofortified crop is introduced as well as for the counterfactual situation where nothing changed. This requires the corresponding assessment of adverse health outcomes due to the micronutrient deficiency in question. Once the DALYs lost are being calculated for both situations they can be compared and the costs that were connected with the development of the biofortified staple crop in question can be attributed to the DALYs saved in the "with-scenario". The result of this approach will be the cost that has to be incurred to save one life through biofortification of the food staple. These costs can, in turn, be compared to the money that is being spent on alternative or complementary approaches to be able to assess the financial effectiveness of biofortification. In preventing iron deficiency Hunt (2002) names for example breast feeding promotion, oral iron supplementation for pregnant women, school health interventions and education campaigns as being – at less than US$ 25 per DALY saved – low-priced interventions. In the case of iron fortification and supplementation he gives costs of US$ 4 and US$ 13 per DALY saved respectively. In the study proposed here the economic case of fighting micronutrient malnutrition through biofortification will be looked at and the result will be put in the wider context of alternative measures.

The DALYs approach is subject to various criticisms, for ethical and equity reasons as well as on methodological grounds. These criticisms will be discussed in more detail in the actual study proposed here. At this point we only want to point out that practically all elements of the DALY calculation are concerned: the disability weights themselves as well as the way they are established, the age-weighting and the discounting are subject to criticism on ethical grounds (Anand and Hansson, 1998 and Lyttkens, 2001). From a methodological point of view the treatment of time as a continuum is being criticised (Elbasha, 2000) and the way the disability weights are being determined (Lyttkens, 2001). However other measures of health are criticised too, which lies in the ethical delicacy of the matter. In our view the DALYs approach is the best available measure, even if its application might lack complete general consensus.

3.2 Overview of iron deficiency and related costs

Iron performs an important task in the human body, where it is essential as a component of enzymes and haemoglobin, the latter of which is important for the transport of oxygen through the body. Deficiency of iron decreases physical and cognitive capacity, delays development and leads to adverse pregnancy outcomes (IOM 2002). Iron status, and by implication iron deficiency, is affected by several factors covering iron intake and iron losses, as is shown in Figure 3-1.

These determinants are in turn subject to further influences. Iron intake depends on individual and dietary factors that influence the bioavailability[6] of the iron consumed: repletion of body iron stores, presence of ascorbic acid and of meat and fish in the food increase the bioavailability of iron, while the presence of tannates, phytates, phosphates and fibres in the food as well as the consumption of eggs and dairy products decreases iron bioavailability (Hallberg 1981 and 2002). Iron loss occurs mainly through the exfoliation

[6] "Iron bioavailability is defined as the amount of ingested Fe [iron] which is absorbed and utilized for normal metabolic functions." (Hurrell 1997).

of cells (and through negligible amounts in urine and sweat). In women iron loss occurs furthermore through menstrual losses, pregnancy and lactation (FAO 1988). The resulting iron status – respectively iron deficiency – can be classified in stages reaching from the mere absence of iron stores to levels of haemoglobin concentration which indicate iron deficiency anaemia (Hallberg and Rossander-Hultén 1991).

Figure 3-1: Determinants of iron status

iron intake				**iron losses/needs**
			→	menstruation
diet	→	physiological iron pool	→	pregnancy
fortification	→		→	growth
supplementation	→		→	infections
			→	exfoliation, sweat & urine

Adapted from Ramakrishnan and Yip, 2002.

The economic consequences of iron deficiency and of iron deficiency anaemia are well established. On the basis of the analysis of ten developing countries Horton and Ross (2003), for example, estimate the annual productivity losses due to iron deficiency to amount to four percent of GDP or to almost US$ 17 per capita in these countries. Focusing on the rationale for investing in the elimination of iron deficiency with regard to children Hunt (2002) points out that proper iron nutrition is a critical factor during brain development in the first three years of life. He underlines further that improved iron status of children raises the efficiency of public expenditure in health and education, as cognitive gains are realised, and that reducing iron deficiency anaemia will lead to improved long-term economic competitiveness due to future productivity gains.

3.3 Further steps to be undertaken

In the actual case study, when looking at the potential future benefits and effectiveness of a biofortified crop, different determinants of the impact of the crop as well as possible variation within these determinants will have to be taken into account. This could be done through the application of different scenarios for different assumptions about their impact. Determinants influencing the effectiveness of a biofortified crop are for example the efficacy of the human body in absorbing the micronutrient in question and the acceptance of the crop by farmers and by consumers. The results obtained can then, in an ex-ante analysis, be compared with the counterfactual situation of not introducing the biofortified crop before drawing the conclusions.

References

ACC/SCN (2000). Fourth Report on the World Nutrition Situation. United Nations Administrative Committee on Coordination Sub-Committee on Nutrition, in collaboration with IFPRI, Geneva.

Anand, Sudhir and Kara Hanson (1998). DALYs: Efficiency versus equity. World Development. Vol. 26, No. 2, pp. 307-310.

Behrman, Jere R. (1995). Household behaviour and micronutrients: What we know and what we don't know. Working Papers on Agricultural Strategies for Micronutrients, No. 2. International Food Policy Research Institute, Washington, D.C.

Behrman, Jere R. and Anil Deolalikar (1989). Is variety the spice of life? Implications for calorie intake. In: Review of Economics and Statistics. Vol. 71, No. 4, pp. 666-672.

Borlaug, Norman E. (2000). The Green Revolution revisited and the road ahead. Special 30th Anniversary Lecture, September 2000. The Norwegian Nobel Institute, Oslo.

Bouis, Howarth E. (1996). A food demand system based on demand for characteristics: If there is 'curvature' in the Slutsky Matrix, what do the curves look like and why? In: Journal of Development Economics. Vol. 51, pp. 239-266.

Bouis, Howarth E. (2002). Three criteria for establishing the usefulness of biotechnology for reducing micronutrient malnutrition. Food and Nutrition Bulletin. (Special issue on biotechnology-derived nutritious foods for developing countries: needs, opportunities, and barriers.) Vol. 23, No. 3, pp. 351-353.

Bouis, Howarth E. and Lawrence J. Haddad (1992). Are estimates of calorie-income elasticities too high? In: Journal of Development Economics. Vol. 39, No. 2, pp. 333-364

Bouis, Howarth E. and Mary Jane G. Novenario-Reese (1997). The determinants of demand for micronutrients: An analysis of rural households in Bangladesh. FCND Discussion Paper No. 32. International Food Policy Research Institute, Washington, D.C.

Brunsø, Karen; Thomas Ahle Fjord and Klaus G. Grunert (2002). Consumer's food choice and quality perception. Working paper no. 77, June 2002. The Aarhus School of Business, Aarhus.

Centers for Disease Control and Prevention (2002). Iron Deficiency – United States, 1999-2000. In: MMWR - Morbidity and Mortality Weekly Report. Vol. 51, No. 40, pp. 897-920.

CIAT/IFPRI (2002). Biofortified crops for improved human nutrition. A Challenge Programme proposal. September 2002. International Centre for Tropical Agriculture (CIAT), Colombia, and International Food Policy Research Institute (IFPRI), Washington, D.C.

DellaPenna, Dean (1999). Nutritional genomics: manipulating plant micronutrients to improve human health. Science. Vol. 285, pp. 375-379.

Dharmasena, K.H. and M. Wijeratne (1996). Analysis of Nutritional Contribution of Homegardening. In: Tropenlandwirt. Vol. 97, pp. 149-158.

Evenson, R.E. and D. Gollin (2003). Assessing the impact of the Green Revolution, 1960 to 2000. In: Science. Vol. 300, pp. 758.

FAO (1988). Requirements of Vitamin A, Iron, Folate and Vitamin B_{12} – Report of a joint FAO/WHO expert consultation. Food and Nutrition Series No. 23. Food and Agricultural Organisation, Rome.

Grivetti, L.E. and B.M. Ogle (2000). Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. In: Nutrition Research Reviews. Vol. 13, No. 1, pp. 31-46.

Grosh, Margaret E. and Paul Glewwe (1995). A guide to Living Standards Measurement Study surveys and their data sets. LSMS Working Paper No. 120. Poverty and Human Resources Division, World Bank, Washington, D.C.

Hallberg, L. (1981). Bioavailability of dietary iron in man. In: Annual Review of Nutrition. Vol. 1, pp. 123-147.

Hallberg, L. (2002). Advantages and disadvantages of an iron-rich diet. In: European Journal of Clinical Nutrition. Vol. 56, pp. S12-S18.

Hallberg, L. and L. Rossander-Hultén (1991). Iron requirements in menstruating women. In: American Journal of Clinical Nutrition. Vol. 54, pp. 1047.

Horton, S. and J. Ross (2003). The economics of iron deficiency. In: Food Policy. Vol. 28, pp. 51-75.

Huang, Jikun and Howarth Bouis (1996). Structural changes in the demand for food in Asia. Food, Agriculture, and the Environment – Discussion Paper, No. 11. International Food Policy Research Institute, Washington, D.C.

Hunt, Joseph M. (2002). Reversing productivity losses from iron deficiency: The economic case. In: Journal of Nutrition. Vol. 132, pp. 794S-801S.

Hurrell, R.F. (1997). Bioavailibility of iron. In: European Journal of Clinical Nutrition. Vol. 51, pp. S4.

IFPRI (2002). Green Revolution – curse or blessing? International Food Policy Research Institute, Washington, D.C.

IOM (2002). Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Food and Nutrition Board, Institute of Medicine, Washington, D.C.

Johns, Timothy (2003). Plant biodiversity and malnutrition: simple solutions to complex problems - theoretical basis for the development and implementation of a global strategy linking plant genetic resource conservation and human nutrition. In: African Journal of Food, Agriculture, Nutrition and Development, online version at http://www.ajfand.net/.

Lyttkens, Carl Hampus (2001). Time to disable DALYs? On the use of DALYs in health policy. Lund University, Lund.

Makrides, Maria; Caroline A. Crowther; Robert A. Gibson; Rosalind S. Gibson and C. Murray Skeaff (2003). Efficacy and tolerability of low-dose iron supplements during pregnancy: a randomized controlled trial. In: American Journal of Clinical Nutrition. Vol. 78, No. 1, pp. 145-153.

OMNI (1998). Micronutrient Fact Sheets: Nicaragua. Country Series, No. 70. The USAID Micronutrient Program (MOST), International Science & Technology Institute, Arlington.

Ramakrishnan, Usha and Ray Yip (2002). Experiences and challenges in industrialized countries: Control of iron deficiency in industrialized countries. Journal of Nutrition. Vol. 132, pp. 820S-824S.

Ravallion, Martin (1990). Income effects on undernutrition. In: Economic Development and Cultural Change. Vol. 38, No. 3, pp. 489-515.

Ruel, Marie T. (2002). Is dietary diversity an indicator for food security or dietary quality? A review of measurement issues and research needs. FCND Discussion Paper No. 140. Food Consumption and Nutrition Division, International Food Policy Research Institute, Washington, D.C.

Serageldin, Ismail (1999). Biotechnology and food security in the 21st century. Science. Vol. 285, pp. 387-389.

UN (2000). United Nations Millennium Declaration. General Assembly resolution 55/2. United Nations, New York.

Underwood, Barbara A. (1999). Micronutrient deficiencies as a public health problem in developing countries and effectiveness of supplementation, fortification, and nutrition education programs: Is there a role for agriculture? For: Improving human nutrition through agriculture: The role of international agricultural research, a workshop hosted by the International Rice Research Institute, Los Baños, organised by the International Food Policy Research Institute, October 1999. International Food Policy Research Institute, Washington, D.C.

Wakimoto, Patricia and Gladys Block (2001). Dietary intake, dietary patterns, and changes with age: an epidemiological perspective. In: The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. Vol. 56, pp. 65-80.

Ward, John O. and John H. Sanders (1980). Nutritional determinants and migration in the Brazilian northeast: A case study of rural and urban Ceará. In: Economic Development and Cultural Change. Vol. 29, No. 1, pp. 141-163.

Weinberger, Katinka (2003). The impact of micronutrients on labor productivity: evidence from rural India. Contributed paper selected for presentation at the 25th International Conference of Agricultural Economists, August 16-22, 2003, Durban, South Africa. Asian Vegetable Research and Development Center, Tainan.

WHO (2003). Diet, nutrition and the prevention of chronic diseases – Report of a joint WHO/FAO expert consultation. WHO Technical Report Series No. 916. World Health Organisation, Geneva.

Wolfe, Barbara L. and Jere R. Behrman (1983). Is income overrated in determining adequate nutrition? In: Economic Development and Cultural Change. Vol. 31, No. 3, pp. 525-549.

World Bank (2002). Basic information document – Nicaragua Living Standards Measurement Study Survey 1998. Documentation, November 2002. Poverty and Human Resources Division, Development Research Group, World Bank, Washington, D.C.

Zimmermann, Roukayatou and Matin Qaim (2002). Projecting the benefits of Golden Rice in the Philippines. ZEF – Discussion Papers on Development Policy Vol 51, September 2002. Zentrum für Entwicklungsforschung, Bonn.