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Review Article

Food-based Approach to Combat Micronutrient Deficiencies

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Cereal-pulse-based diets of developing countries like India are qualitatively deficient in micronutrients (vitamins and minerals) – “the hidden hunger”. Micronutrient deficiencies adversely impact health and consequently, medical expenditure and productivity. Approaches for combating dietary micronutrient deficiencies include: pharmaceutical supplementation; food fortification (salt, wheat flour, milk, oil) or addition of micronutrient powder to cooked food; and dietary diversification through nutritionally sensitive agriculture. Bio-fortification utilising conventional breeding and genetic engineering can help to develop micronutrient-rich varieties of plant foods.

In India, supplementation programmes like, iron-folic acid supplementation to combat anaemia due to iron deficiency and massive dose vitamin A programme to combat vitamin A deficiency have had limited impact, perhaps due to administrative infirmities and lack of awareness and compliance. Food fortification is a promising medium-term approach. It needs careful planning, in terms of items to be fortified, type and quantum of nutrients to be added, food habits, monitoring etc. Iodine fortified salt has helped reduce the incidence of iodine-deficiency disorders. Salt fortified with combination of iodine and iron (double fortified salt-DFS) has been developed and needs to be scaled up. Efficacy of fortified staple foods and fortification of cooked food with multiple micronutrient powder have been established but require implementation at national level. Dietary diversification by leveraging agriculture for nutrition security (LANS) is a long-term, sustainable strategy. It has positive impact if accompanied by behavioural change communication (BCC) and women’s participation. Studies in India and countries of South Asia and Africa have shown that, homestead production of micronutrient-dense vegetables and fruits particularly green leafy vegetables can increase the intake of micronutrients. Backyard poultry with high egg-yielding breeds and fewer birds has shown positive impact on household egg consumption. However, LANS cannot be a stand- alone strategy when farm holdings are very small. It requires integration of a package of interventions and proper monitoring.

Keywords: **Micronutrient Deficiencies; Hidden Hunger; Food Fortification; Dietary Diversification; Micronutrient-Rich Foods; Homestead Gardens; Backyard Poultry**

Introduction

Malnutrition is the curse that India continues to fight despite impressive economic growth and reduction in poverty. The term malnutrition includes both under-nutrition (with respect to macronutrients-energy, protein and fats and micronutrients-vitamins and minerals), as well as overweight and associated problems. Even while India continues to grapple with the pre-transition diseases like infections and under-nutrition, post-transition problems of over nutrition-obesity and associated degenerative diseases are on the rise. What is often not realized is under-nutrition in early life (first 1000 days from conception) not only affects physical growth, mental development and immunity, but also epigenetically predisposes to the age-onset chronic diseases (Barker hypothesis) like obesity, hypertension, diabetes, cardiovascular diseases etc. (Robinson, 2001).

Surveys done in India by the National Nutrition Monitoring Bureau (NNMB), show that cereal-pulse-based Indian diets are qualitatively deficient in micronutrients (NNMB, 2012). If calorie requirement

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is met, protein requirement is met in most households. However, deficiencies of micronutrients like iron, vitamin A, riboflavin, folic acid and vitamin C persist. NNMB surveys do not give information on intakes of zinc, vitamin B12 and vitamin D, whose deficiencies are also of concern.

Time-trends revealed through periodic NNMB surveys between 1975-77 and 2011-12 show very low dietary intakes of fat and most of the protective foods like pulses, milk and milk products, green leafy vegetables and fruits. The data also highlight significant drop in the consumption of cereal and millets from about 500 grams per day to 360 grams per day, with alarming disappearance of millets. This has resulted in the change in dietary diversity and quality. Faulty infant and young child feeding (IYCF) practices and lack of dietary diversity in complementary foods are the major causes of under-nutrition and micronutrient deficiencies in infants and pre-schoolers.

Consequences of Micronutrient Deficiencies-Hidden Hunger

Unlike protein calorie malnutrition which manifests as growth retardation (stunting) and wasting; adverse consequences of micronutrient (MN) deficiencies are not obvious and often referred to as the 'hidden hunger'. Clinical manifestations of severe deficiencies of many micronutrients like beriberi (vitamin B1 deficiency), pellagra (niacin deficiency), and rickets (vitamin D deficiency) have become diseases of yester years. Even goitre caused due to iodine deficiency and blindness due to vitamin A deficiency is relatively rare. However, other ocular manifestations of vitamin A deficiency, like, night blindness and Bitot's spot are seen among children and pregnant women. Yet, sub-clinical deficiencies of micronutrients, identified through dietary intake and biomarkers, has serious consequences, in terms of impaired growth, immunity, learning and cognitive ability, work performance, and pregnancy outcomes. Besides human suffering, MN deficiencies also affect economic growth by reducing productivity and increasing health care cost. MN deficiencies together are estimated to be responsible for about 35% of child deaths, and 11% of total disease burden (Roy *et al*., 2009). Estimates of economic cost of micronutrient malnutrition (iron, zinc, vitamin A and iodine) in India, using the index of Disability Adjusted Life Years (DALYs) lost, have varied from 0.8% to 2.5% of GDP (Stein and Quaim, 2007). World Bank in earlier assessments has reported higher losses (World Bank, quoted by Stein and Quaim, 2007). According to the reports of various agencies, micronutrient deficiencies are estimated to cost India, $ 2.5 billion each year (Micronutrient Initiatives and UNICEF 2004, quoted in India Health Report - Nutrition 2015).

Recently, an index of micronutrient deficiencies termed as ''Global Hidden Hunger Index" (HHI) to "help prioritise programme assistance, and to serve as evidence-based global advocacy tool" has been developed, based on National data on stunting (as proxy for zinc deficiency), iron-deficiency anaemia and low serum retinol levels, among pre-school aged children from 149 countries (Muthayya *et al*., 2013). Most countries with alarmingly high HHI were from the Sub-Saharan Africa region. The only two countries from Asian region with alarmingly high HHI were; India and Afghanistan. In 36 countries, home to 90% of world's stunted children, deficiencies of micronutrients were responsible for 1.5-12% of the total DALYs lost. These estimates do not include iodine deficiency. If other deficiencies like those of iodine, folic acid, vitamin B12, and vitamin D are also included, the figures of DALYs lost would be much higher. Interestingly, HHI showed strong correlation with Human Development Index (HDI) 2007, but not percentage under-nutrition, suggesting the importance of addressing "hidden hunger" in order to reduce general deprivation, improve health and education and vice versa. It also suggests that, judging adequacy of food supply simply on the basis of energy sufficiency as is often done, does not capture the true picture of food adequacy. It misses out on diet quality which encompasses the entire spectrum of dietary diversity.

Among the micronutrients, iron is of particular concern. According to the recent India Health Report on Nutrition (2015), 55.3% women aged 15-49 years, and 69.5% children aged 6-59 months old suffer from anaemia, primarily due to iron deficiency. Dietary deficiency of iron from habitual Indians diets high in phytates, which reduces absorption, is the major cause. Deficiency of other vitamins like vitamin A, folic acid, vitamin B12, vitamin C and zinc may also contribute.

Strategies for Combating Micronutrient Deficiencies

Both dietary and non-dietary factors, such as; access to clean drinking water and sanitation, health care, purchasing power, women's education and empowerment, contribute to micronutrient inadequacy. The non-dietary factors, though important, are outside the scope of this chapter. Pharmaceutical supplementation - a short term strategy is expected to produce quick remediation and is being tried in India for combating anaemia, and vitamin A deficiency. However, though a programme to supplement pregnant and lactating women and pre-school children with iron and folic acid (the National Nutritional Anaemia Prophylaxis Programme) has been operational in India since many decades, and now expected to cover adolescence (National Iron Plus Initiative), anaemia persists. Administrative infirmities and poor compliance due to lack of awareness among the people may contribute to this failure. Since the national programme provides only iron and folic acid, suggestion has been made to include other micronutrients like vitamin B12, and zinc (which also have a role in erythropoiesis) and vitamin C, which facilitates iron absorption. Massive dose vitamin A programme for children also has been in place since many years. Though the severity of vitamin A deficiency has declined, it cannot be attributed to this programme, due to its patchy implementation. Some public health experts argue for rethinking of this programme, but others oppose such a move.

The dietary strategies include fortification of processed foods or cooked foods which are medium term strategies. The long term and sustainable strategies include; dietary diversification, health and nutrition education (HNE), bio-fortification and transgenic method to improve the nutrient content and bio-availability of micronutrients in habitual diets.

Food Fortification

Historically, addition of nutrients has been practiced as a means of restoring or enriching lost nutrients during industrial processing of wheat flour, used for preparing bread. Over the years this technology has become a global food fortification strategy to address deficiencies of many nutrients. particularly, that of water soluble vitamins; such as vitamins B1, B2, niacin, B6, B12 and folic acid and minerals such as iron. Food fortification has been defined as "Addition of one or more essential nutrients to a food, whether or not it is normally contained in the food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the population or specific population groups" (FAO, 1995). It is ranked as the best global welfare investment, as this technology offers very good opportunity to improve lives and accelerate development of a country, at low cost and in very short time.

Several beneficial effects of fortification have been reported. Strong evidence is presented in literature, with respect to decreased incidence of neural tube defects, following fortification of wheat flour with folic acid, goitre and iodine deficiency-related disorders, following fortification of salt with iodine. Wheat flour fortification has been widely advocated in developing countries and WHO/FAO have given guidelines to be followed for fortification in 2006 (WHO/FAO, 2006). Over the years, many countries have focussed on wheat flour fortification with iron and folic acid. However, a recent systematic analysis of research data has shown limited evidence of the effectiveness of wheat flour fortification, in reducing anaemia but showed evidence of effectiveness in reducing prevalence of low ferritin in women of reproductive age (Pachón *et al*., 2015). Another systematic analysis and meta analysis concerning impact of iron-fortified foods (all foods) on haemoglobin concentration in children less than 10 years of age showed a significant impact of iron fortification on haemoglobin concentration, suggesting that food fortification with iron is a good strategy to correct iron-deficiency anaemia among children (Athe *et al*., 2014). Some inconsistencies may be due to the fact that, implementation of fortification strategies requires a clear understanding of the context of population dynamics.

Studies in India

Fortification of salt with iodine has been a major public health success in India (Pandev *et al*., 2013). To address the dual problem of iodine and iron deficiency, the National Institute of Nutrition (NIN), Hyderabad developed iron-fortified, iodised salt -double fortified salt (Rao, 1994). The efficacy of this salt in reducing anaemia has been tested by NIN (Nair *et al*., 1998, Sivakumar and Nair, 2002) and, more recently, by Joshi and Nair (2014). The technology has been transferred to leading salt manufacturers (Ranganathan *et al*., 1996). Other, relatively more expensive formulations have also been developed, adding value to the concept and technology (Vinodkumar *et al*., 2007; Andersson *et al*., 2008; Haas *et al*., 2014).

There are many challenges for micornutrient fortification in India. These include: 1. Need for clear understanding of the context of population dynamics, 2. Program design and implementation, 3. Single vs. multiple micronutrients, 4. Technology of fortification, 5.Mandatory fortification and potential adverse effects, 6. Monitoring and evaluation, 7. Food synergies to accelerate efficacy.

For food fortification to be successful, there has to be a conscious effort for popularizing dietary diversification with a view to enhance bioavailability of certain micronutrients, such as; iron (food synergies -inclusion of fruits high in vitamin C in each meal to enhance absorption) and vitamin A (inclusion of some fat with beta carotene- rich fruits and vegetables to promote absorption) (Nair *et al*., 2013 and 2015 a). This will reduce the time required for visible, significant change in end-line markers of interest, especially for anaemia.

Currently, in India, common salt is being fortified with iodine on a mandatory basis. Though DFS was mandated in Government sponsored food and nutrition programmes like mid-day meal in schools (MDM) and ICDS feeding programmes in 2011 (Ministry of Women & Child Development, 2011), its implementation is tardy and there is a need to scale up its production, distribution, monitoring and long-term implementation in the country.

Fortification of wheat flour and rice with B vitamins and minerals, and, milk and oil with vitamin A and D need to be considered for mass and mandatory fortification. Global evidence (WHO/FAO, 2006) and limited evidence from India, show fortification of wheat flour (Muthayya *et al*., 2012, Nair *et al*., 2015 b), rice (Radhika *et al*., 2011), milk (Khadgawat *et al*., 2013) and point of use fortification of foods (fortifying cooked food at home or at Aganwadi centers) with multiple micronutrient powders (WHO, 2011) are all strategies with potential for scale-up.

As a policy, fortification needs to be mandatory in certain foods for it to benefit the population at large. The policy should also ensure that, this is integrated with the different national programs in existence, so that the collective exposure will never be beyond the upper limits of intake. The major challenges to this policy approach are the involvement of the unorganised sectors in the food production industry, technological challenges in setting standards, creating mandated legislation and regulations, partnering with industry, and then, the mammoth task of monitoring. There needs to be a behaviour change communication (BCC) program for all stakeholders and capacity building of producers, as well as, the enforcers. The regulatory authorities need to continuously monitor the intake levels of the population, not just to look at nutrients which are deficient in the diet, but also to ensure that nutrients are not consumed at levels beyond the upper tolerable intake levels.

Dietary Diversification for Food and Nutrient Security

Food Security should address the issue of quantity, as well as quality of the diet, in terms of food groups: cereals and millets, pulses and legumes, milk and meat products, fruits and vegetables and fats and sugars. According to FAO; for Food security, “all people, at all times, should have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life” (FAO, 2006). A balanced diet should supply the required quantity of energy, protein, fat, carbohydrates, vitamins and minerals at household and individual level, based on age, gender and physiological status.

The importance of food-based strategies to combat micronutrient deficiencies was advocated by FAO (Rome) way back in 1992, at the International Conference on Nutrition. This strategy promotes dietary diversification, using locally available foods to satisfy local food habits and facilitates recommended nutrient intakes. Unlike supplementation or fortification, which can address the deficiency of only select nutrients, dietary diversification is a more holistic and balanced approach with little or no danger of toxicity. It demands creating an enabling environment of awareness, and ensuring access at affordable cost to a variety of foods, within and across food groups to obtain adequate micronutrients. In a rural area where food is produced, this can be achieved by leveraging nutrition into cropping pattern and promoting production of livestock-based foods at district, village or household level. In urban areas, nutritionally promotive marketing strategies are needed. In some countries, urban agriculture has become an important part of food production. Hazards of city-grown food due to greater chemical pollution have to be monitored (Meharg, 2016).

The Food Security Act of India provides entitlement to cereals and millets at subsidised rate to 75% resource poor population. Unfortunately the food basket does not include other food groups. Public should be educated through multi-media channels to utilise the money saved in buying staples, for purchasing pulses, vegetables, fruits and foods of animal origin, particularly poultry and milk. Dietary diversification is culturally acceptable and sustainable, provided, the community is aware of the importance of consuming diverse foods, particularly, the protective foods like; pulses, vegetables, fruits, and foods of animal origin and they are available at affordable costs.

Supplying micronutrients through diet, by and large, obviates the danger of excess dosing (vitamin A) and imbalance in micronutrients (folate and vitamin B12), because of biological regulatory mechanisms, at the level of absorption.

Foods Rich in Micronutrients

In cereal-pulse-based Indian diets, cereals by virtue of the quantity consumed, are the major source of minerals (iron, zinc, calcium) and B-vitamins like thiamine (vitamin B1), and niacin, and to a lesser extent vitamin B2 and folic acid. Pulses also contribute, to all the above mentioned micronutrients being more micronutrient dense, besides being rich in proteins. Pulse production has not kept pace with increase in the population and they are going out of reach of the poor, threatening protein deficiency. Millets like sorghum (*Jowar*), pearl millet (*Bajra*), and minor millets, like finger millet (*ragi*), and others are better endowed in micronutrients than rice (Table 1). They are the grains of the future, being climate resilient, and needing lesser water. Apart from nutrients, millets are also a good source of health, promoting dietary fibre and antioxidants tannins and phytates. Unfortunately, with the emphasis on cereals in green revolution, millets have become orphan grains and their area of cultivation and consumption has declined. Course correction is urgently needed.

Cereals, millets and pulses are very poor source of vitamin A and vitamin C. These nutrients have to be derived from vegetables and fruits. Citrus fruits (40-64 mg/100g), guava (200 mg/100g), papaya (57 mg/100g) and Indian gooseberry (amla 600 mg/100g) are rich in vitamin C. Being very heat labile; vitamin C is lost during cooking, and therefore, nutrition education with regards to minimal processing of vegetables to retain the vitamins needs to be imparted. Plants lack vitamin B12, and hence, foods of animal origin like milk, eggs, meat, and fish are absolutely necessary to meet even the minute daily requirement of 1 μg of vitamin B12. Contaminating bacteria and to some extent intestinal bacteria supply some vitamin B12. Plants also lack preformed vitamin A, but yellow-orange vegetables and fruits and dark green leafy vegetables (GLV) are a good source of provitamin

Table 1: Nutrient content of 100 g cereals and millets

Grain/nutrient	Bajra	Jowar	Ragi	Rice-milled	Maize	Wheat-flour
Protein g	11.60	10.40	7.30	6.80	11.10	12.10
Calcium mg	42.00	25.00	344.00	10.00	10.00	48.00
Iron mg	8.00	4.10	3.90	3.20	2.30	4.90
Zinc mg	3.10	1.60	2.30	1.40	2.80	2.20
Vitamin B1 mg	0.33	0.37	0.42	0.06	0.42	0.49
Vitamin B2 mg	0.25	0.13	0.19	0.06	0.10	0.17
Folic acid μg	45.50	20.00	18.30	8.00	20.00	36.60
Fibre g	1.20	1.60	3.60	0.20	2.70	1.20

Source: Gopalan *et al*., 1989, reprinted, 2011

A- β carotene. Table 2 lists some Indian vegetables and fruits rich in β carotene. Animal foods like meat, fish, and liver are very good source of easily available preformed vitamin A. Bio-availablity of vitamin A from plant sources varies depending on the plant matrix, cooking method and fat content.

Bio-availablity of iron from animal foods, which contain haem iron is much better than that from plant foods which contain non-haem iron. Bio-availablity of minerals from plant foods varies based on the plant matrix, method of cooking, and synergies and competition with other nutrients in the diet, which can favour or obstruct absorption.

Amongst the vegetables, green leafy vegetables (GLV) are very rich in all micronutrients (Tables 3, and 4). They are easy to grow and are available throughout the year. Yet, NNMB surveys show that the consumption of GLV is less than 45% of daily requirement. Besides vitamins, minerals and trace elements, vegetables and fruits are also rich source of fibre and health- promotive phytochemicals which protect against degenerative diseases (Bamji and Bhaskarachari, 2015). Apart from the cultivated varieties of vegetables listed in the tables, there are many wild growing indigenous varieties of vegetables, which are even more micronutrient dense (Bamji and Bhaskarachari 2015).

Table 2: Commonly consumed vegetables and fruits other than GLV rich in β carotene

Name of the foodstuff	β carotene mg/100 g
Carrot (*Daucus carota*)	6.460
Mango, ripe (*Magnifera indica*)	1.990
Sweet Potato (Yellow) (*Ipomoes batatas*)	1.810
Yellow Pumpkin (*Cucurbita maxima*)	1.160
Chillies, green (*Capsicum annuum*)	1.007
Papaya, ripe (*Carica papaya*)	0.880
Tomato, ripe (*Lycopersicon esculentum*)	0.590

Source: Gopalan *et al*., 1989, reprinted, 2011, Table reproduced from Bamji and Bhaskarachari (2015)

Table 3: Vitamins in commonly consumed Green Leafy Vegetables (GLV) in India

Name of the foodstuff (Local/botanical name)	β carotene mg /100g	Thiamine	Riboflavin	Niacin	Folates µg /100 g	Vitamin C mg/ 100g
Agathi (*Sesbania grandiflora*)	15,440	0.21	0.09	1.2	-	169
Amaranth (*Amaranthus caudatus*)	8.340	0.03	0.3	1.2	149	99
Ambat chukka (*Rumex vesicarius*)	2.800	0.03	0.06	0.2	125	12
Beet Greens (*Beta vulgaris*)	5.862	0.26	0.56	3.3	15	70
Cabbage (*Brassica oleracea* var. *capitata*)	0.120	0.06	0.09	0.4	23	124
Celery leaves (*Apium graveolens* var. *dulce*)	3.990	0.02	0.11	1.2	36	62
Colocasia leaves (*Colocasia anti-quorum*)	5.920	0.06	0.45	1.9	126	63
Coriander leaves (*Coriandrum sativum*)	4.800	0.05	0.06	0.8	62	135
Drum stick leaves (*Moringa oleifera*)	19.690	0.06	0.05	0.8	40	220
Fenugreek leaves (*Trigonella foenum graecum*)	9100	0.04	0.31	0.8	-	52
Gogu (*Hibiscus cannabinus*)	6’.970	0.07	0.39	1.1	-	20
Knol-Knol Greens (*Brassica oleracea* var. *caulorapa*)	4.146	0.25	0.10	3	194	157
Lettuce (*Lactuca sativa*)	1.100	0.09	0.13	0.5	38	10
Basella (*Basella rubra*)	2.840	0.03	0.16	0.5	-	87
Mint (*Mentha spicata*)	5.480	0.05	0.26	1	114	27
Mustard leaves (*Brassica campestris* var. *sarason*)	2.622	0.03	0.11	0.80	187	33
Ponnanganni (*Alternathera sessilis*)	1.926	0	0.14	1.2	-	17
Spinach (*Spinacia oleracea*)	2.740	0.03	0.26	0.5	123	28

Source: Gopalan et al., 1989, reprinted, 2011. Table reproduced from Bamji and Bhaskarachari (2015)

Table 4: Minerals in commonly consumed green leafy vegetables

Name of the foodstuff (Local/botanical name)	Ca	P	Fe	Mg	Na	K	Cu	Mn	Mo	Zn	Cr
	(mg/100g)						(µg/100g)				
Agathi (*Sesbania grandiflora*)	1130	80	3.9	-	-	-	-	-	-	-	-
Amaranth (*Amaranthus Caudatus*)	200	40	2.32	122.1	230	341	78	365	130	178	6.9
Ambat chukka (*Rumex vesicarius*)	63	17	0.75	123.7	-	-	42	403		271	6.1
Beet Greens (*Beta vulgaris*)	380	30	16.2	70	226	762	75	321	-	380	-
Cabbage (*Brassica oleracea* var. *capitata*)	39	44	0.8	31.7	18	170	22	183	78	298	4.7
Celery leaves (*Apium graveolens* var. *dulce*)	230	140	6.3	52	35.5	210	10	100	-	130	-
Colocasia leaves (*Colocasia anti-quorum*)	460	125	0.98	32.8	3	648	184	-	-	410	11.4
Coriander leaves (*Coriandrum sativum*)	184	71	1.42	31.4	58.3	256	141	497	1120	323	13.5
Drum Stick leaves (*Moringa oleifera*)	440	70	0.85	41.7	9	259	69	375	-	163	9.5
Fenu Greek leaves (*Trigonella foenum graecum*)	395	51	1.93	33.8	76.1	31	96	229	400	358	5.8
Gogu	172	40	2.28	66.1	-	-	84	298	-	272	5.2
Knol-Knol Greens Greens (*Brassica oleracea* var. caulorapa)	740	50	13.3	31	40	296	10	100	ND	190	-
Lettuce (*Lactuca sativa*)	50	28	2.4	30	58	33	80	300	1.3	180	6.7
Mayalu (*Basella rubra*)	200	35	10	-	-	-	-	-	-	-	-
Mint (*Mentha spicata*)	200	62	15.6	60.3	-	-	179	572	-	438	8.2
Mustard leaves (*Brassica campestris* var. *sarason*)	155	26	16.3	32	25	354	147	480	-	200	-
Ponnanganni (*Alternathera sessilis*)	510	60	1.63	46.2	-	-	185	464	-	-	948
Spinach (*Spinacia oleracea*)	73	21	1.14	63.5	58.5	206	95	559	10	295	4.8

Source: Gopalan *et al*., 1989, reprinted, 2011, Table reproduced from Bamji and Bhaskarachari (2015)

Dietary Diversity Score

Assessment of dietary diversity in relation to micronutrient adequacy, using acceptable scoring methods has been attempted. The most commonly accepted score is the Dietary Diversity Score (DDS), which is defined as: the measure of number of food groups consumed over the reference period by the individual. Classification of food groups has varied across studies and between age groups within a country. For details see (Nair *et al*., 2015a).

Farm-Based Approach to Combat Hidden Hunger

Though India is amongst the top two producers of milk, fruits & vegetables and fish in the world, diets of the poor are grossly deficient in these foods. Main reasons are: insufficient production to meet the needs of a large population; inequity in distribution, due to poor unaffordability, and ignorance about the health importance of these foods. The farmer who produces these foods prefers to sell them rather than consume at home. The real problem is competition between economics *vs* nutrition, with very small farm holdings and inability to comprehend the amount needed to be consumed for health. Hitherto, agriculture is viewed as a source of income, export, and at best, means to quench energy and protein hunger. Its relevance to micro–nutrient importance, is often overlooked. Unfortunately, human nutrition is not taught to farm graduates, at any level to sensitise them and equip them for nutritionally sensitive agriculture extension work. In most developing countries, like India, over 70% of families live in rural areas with farming as the major occupation. With proper advice on cropping patterns to support cultivation of micronutrient-dense crops at household and village level, and education (BCC) of the community regarding the importance of balanced diet and nutrition for health; agriculture interventions have the potential to reduce multiple micronutrient deficiencies (Shetty, 2011). A detailed review of past and recent experiences on this aspect has been done by Arimond *et al*. (FAO, 2011). Along with agricultural intervention and BCC, access to safe drinking water and disease-free environment are very necessary for making an impact on nutrition status. Women should be the focus of this approach, to empower them.

Studies in India on Homestead Food Production

Homestead Gardens

During 90s, studies were done in Andhra Pradesh by the National Institute of Nutrition (NIN)-Hyderabad and in West Bengal by the All India Institute of Hygiene and Public Health (AIIHPH), to examine the feasibility and impact of homestead gardening on vitamin A deficiency (Vijayaraghavan *et al*., 1997; Chakravarty, 2000). Both the studies combined horticultural interventions like distribution of planting material (seeds or saplings) of β-carotene (provitamin A)-rich plants to the households, along with technical know how and do-how regarding raising them, and education on health and nutrition. Impact was assessed through assessment of weekly frequency of intake of vitamin A-rich foods; ocular signs of vitamin A deficiency like Bitot's spots in pre-school children and knowledge attitude and practice surveys among mothers with pre-school children, pertaining to vitamin A deficiency and its prevention, and vitamin A-rich foods. Local government functionaries were kept in the loop. The Andhra Pradesh study included 20 villages from two agro-climatic regions. In West Bengal, after a pilot study in 5 villages, the experiment was extended to three diverse blocks.

Both the studies showed remarkable increase in the number of households raising home gardens with β-carotene-rich plants after the intervention. Frequency of consumption of vegetables and fruits rich in β-carotene and knowledge of mothers regarding ocular signs of vitamin A deficiency, and foods rich in vitamin A showed significant increase. The well entrenched false belief of avoiding papaya during pregnancy also decreased but marginally. While, in West-Bengal, there was significant reduction in Bitot's spots, in Andhra Pradesh the impact was less remarkable and statistically not significant.

In more recent years, an NGO, Dangoria Charitable Trust has been working on the concept of Diversification from agriculture to nutritionally-promotive and environmentally sustainable horticulture in the Medak district of Telangana (Bamji *et al*., 2011; Murty *et al*., 2016). While the earlier, study (Bamji *et al*., 2011), used a non-targeted approach of including all households who showed interest; in the later study, focus was on pregnant women and mothers with pre-school children who had registered at the Integrated Child Development Services centres (ICDS Anganwadi). Most land holdings in the selected villages from 4 mandals (about 25,000 population per mandal) are small or marginal. Despite water scarcity, water guzzling crops like paddy and sugarcane are grown, using bore well water. Maize is grown in *rabi* and *kharif* seasons, mostly as rain-fed crop. Red gram is sometimes inter-cropped with maize. Before the intervention, about 30% households grew some vegetables and had one or two trees of fruits like mango, papaya, guava, and sapota, and drumstick and curry leaves. Farmers were persuaded to set aside small plots of land (quarter acre or less), from traditional crops to raising nutrition gardens near their homes or in their fields by giving planting material for nutrient-dense vegetables and fruits, like common varieties of GLV, beans, tomatoes, ladies finger and others. Finger millet (ragi), and fodder grass, were also introduced in a few farms. Green methods of farming, such as vermi composting and use of botanical pesticides made from neem seed, or chilli-garlic decoction, were taught to reduce the use of chemicals. Farm demonstrations of bio-fortified crops like iron-rich pearl millet (bajra) and orange-flesh sweet potato rich in β carotene were given. Farmers were explained that such diversification would not only improve household micronutrient security, but also save water and raise the water table. Health and nutrition education (BCC) was an important part of the study. Like in the earlier studies, impact was assessed through records of increase in the households raising gardens, and land diverted; acceptance of farm technologies; frequency and quantity of vegetables in general and GLV in particular consumed at home, and initial and end-line (after 3 years) knowledge attitude and practice surveys of mothers with pre-school children, on issues of nutrition and health to judge the change in knowledge and practice.

With some advocacy, homestead gardening was accepted very well. There was significant increase in the weekly frequency and quantity of GLV consumed, but, little or no change in the consumption of other vegetables. Despite emphasising the need to consume home-grown vegetables at home, particularly for feeding women and children; 25-50% of vegetables grown at home were sold. For poor families, income is more important than nutrition. However, in families that did not raise homestead gardens (Controls), there was a significant decrease in the consumption of vegetables, over the three year period of study, due to price rise, suggesting that home-grown vegetables at least shielded the poor families from increase in the market price of vegetables (Bamji *et al*., 2011). Apart from home gardening, poverty alleviation programmes are needed to ensure household food security. There was remarkable improvement in the knowledge of mothers on issues, such as; components of a balanced diet, importance of protective foods, healthy cooking practices, correct breast-feeding and complementary feeding practices etc. Some wrong practices such as avoiding papaya during pregnancy and discarding excess water after cooking rice are hard to change. Records maintained by the anganwadi worker showed significant decline in the percentage of 6-24 months old children who were underweight. (Murty *et al*., 2016). For community projects of this nature, BCC is extremely important, along with technological interventions.

MS Swaminathan Foundation, Chennai, India is currently experimenting with "A farming system model to leverage agriculture for nutritional outcomes" (farming systems for nutrition-FSN) in Wardha District of Vidarbha region of Maharashtra, and Koraput district of Odisha (Das *et al*., 2014). The objective is to demonstrate the feasibility of nutrition-sensitive agriculture. The main components of the model are: 1) survey to identify the major nutritional problems, 2) design context specific suitable agricultural interventions to address the local nutritional problems, 3) built-in specific nutritional criteria, 4) improve small farm productivity and profitability, 5) undertake nutrition awareness programmes, and 6) introduce monitoring systems for assessing impact on nutrition outcomes.

Homestead Production of Livestock

Though India is the largest producer of milk, and in recent years, there has been a quantum jump in the production of poultry, the benefits have largely gone to the urban population and have not impacted the nutrition of the poor. This is largely because, income rather than improving nutrition of the family was the primary aim, and nutrition education was a casualty. Goat rearing is widely done by the marginalised farmers, but except in some communities, goat milk which is nutritious is not consumed. Income can help household food security, if it is backed by BCC to use the income generated for food.

Among foods of animal origin, poultry egg has a favourable cost-benefit ratio. Since 1985, consumption of animal meat has declined, but that of poultry egg and meat is increasing (Pica-Clamarra & Otte 2009, and Government of India, 2006). Egg is a wholesome food rich in good quality protein and all micro nutrients including vitamin B12. Backyard poultry (BYP) improves the outreach of eggs to rural areas. In recent years, improved breeds which can lay over 160 eggs per bird, per year, compared to the local breeds which lay only 30-40 eggs per year have been developed (Rao and Pretam, 2009).

Positive impact of BYP, using high egg-yielding breeds, coupled with BCC was demonstrated in studies from Medak district of Telangana (Murty *et al*., 2013; Murty *et al*., 2016). There was over 2 fold increase, in the weekly frequency and quantity of eggs consumed by the participating households. When each household receives only few birds, the few eggs produced are consumed at home rather than sold. The families purchased 4 hens and one cock was given free as incentive.

BYP needs little investment, space and water. Since these birds graze, expenditure on feed is also minimal. However, for this technology to succeed, care is needed to ensure regular supply of pedigree female birds or measures to prevent contact with male birds of non-descript local breeds. Otherwise, being free roaming birds, there will be deterioration in the improved breeds.

International Studies on Homestead Food Production

Homestead food production including vegetables, fruits and livestock for local food security has been extensively promoted by international agencies like FAO, and non-governmental agencies like Hellen Keller International, in countries of Africa and SE Asia. A study in South Africa showed the effectiveness of integrating home gardening with community-based growth monitoring activities in alleviating vitamin A deficiency. There was significant reduction in the prevalence of low serum vitamin A (< 20µg/dL) from initial 58% to 34%. There was no impact on growth of the children (Faber and Benade, 2003).

Hellen Keller International has implemented an extensive programme in Bangladesh, Cambodia, Nepal and Philippines to increase access to micronutrient-rich foods in poor communities. The programme included setting-up improved homestead gardens, and backyard poultry, along with nutrition education (Bushamuka *et al*., 2005; Iannoti *et al*., 2009; Rahman *et al*., 2008; Talukdar *et al*., 2010). Weekly frequency, as well as, quantity of vegetables and eggs consumed by mothers and pre-school children showed a quantum increase. There was significant improvement in the mother's knowledge of nutrition. Significant reduction in the prevalence of anaemia was seen in Bangladesh and Philippines. Families also earned some income, by selling excess vegetables.

Despite all these success stories, it should be noted that homestead production alone may not meet the household's dietary requirement for vegetables, fruits and animal products, due to very small land holdings, and farmer's preference for growing crops that fetch income, rather than worry about nutrition. BCC stressing the importance of dietary diversification and quantities of protective foods to be consumed for health, along with poverty alleviation programmes is needed. A mission-mode approach leveraging agriculture for nutrition security (LANS) is the need of the hour. For that, the agriculture extension workers have to be knowledgeable about nutrition, and be able to contextualise farming strategies to the local farming practices and dietary preferences. Krishi Vignan Kendras and well-informed anganwadi workers can play an important role. Corporate sector can also contribute, through their corporate social responsibility. Introduction of right farming technologies to improve soil health, water management, biotic and abiotic stress resistant varieties, as well as biofortified varieties, and technologies to minimise on-farm and off-farm wastage can go a long way in improving access to micronutrient-rich foods.

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