# MICRO-NUTRIENT SECURITY FOR INDIA – PRIORITIES FOR RESEARCH AND ACTION

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# PREFACE

About a year back INSA had given a more formal shape to its activities aimed at recommending governmental action and informed public debate on issues involving science and technology. This was done by forming a Science Policy Cell within INSA with a mandate to strengthen and systematize this important area of INSA's work in the realm of public policy.

This report is the first printed product of this newly formed cell.

It offers a set of recommendations for action and urgent research on Micronutrient Security for India. It was prepared jointly with the Science and Society section of INSA under the leadership of Dr Mahtab S Bamji, the Vice president for Science and Society at INSA and a very distinguished Nutritionist.

She has prepared the report after numerous drafts based on consultations with other experts in the country through meetings and electronic correspondence.

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# CONTENTS

# MICRO-NUTRIENT SECURITY FOR INDIA–PRIORITIES FOR RESEARCH AND ACTION

## Introduction

Recently, the Indian National Science Academy (INSA) brought out a position paper on "Nutrition Security for India–issues and the way forward" based on deliberations in a symposium and subsequent discussions. This policy paper has been prepared as an off-shoot of the earlier effort, to focus specifically on priorities for research and action, for addressing the issue of micronutrients (MN) deficiencies — the hidden hunger. (INSA, 2009 www.insa.ac.in). It is beamed at researchers, funding agencies and policy makers and planners.

Malnutrition in India, particularly among women, children and adolescents is an emergency needing immediate attention if the country has to have inclusive growth and development. Health portfolio tends to concentrate on infectious diseases (vaccination, oral rehydration, treatment of infections), and non-communicable diseases like cancer and cardiovascular diseases. Important as these are, nutrition cannot be subsumed under these. Nutrition has to be the basis of judging national development. Without good nutrition, neither communicable nor non-communicable diseases can be controlled. Malnutrition is the worst form of non-communicable disease and is an important risk factor for chronic diseases at a later date. Maternal malnutrition has multigenerational adverse effects on human health and development.

Nutrition Security implies 'Physical, economic and social access to balanced diet, clean drinking water, safe environment, and health care'. Nutrition literacy and leadership at all levels is needed to understand and act. After 63 years of independence, India has among the highest incidence of under-nutrition in the world[1]. Almost 50% of children under 5 are under weight (weight for age) and stunted (height for age). Over 30% of adults are also undernourished. Besides deficiency of calories and protein, deficiency of micronutrients (MN) (vitamins and minerals) is rampant[2,3,4]. MN deficiency is referred to as the hidden hunger since often times it is not an obvious killer or crippler, but extracts heavy human and economic cost. Though anthropometric deficits are attributed to protein calorie malnutrition, MN deficiencies contribute significantly, because MNs are needed for utilisation of proteins and calories and to fight infections from a young age.

MN deficiency has a complex aetiology. Besides poor diet (due to poverty, ignorance, low agricultural productivity, and cultural factors); inadequate access to safe drinking water, clean disease-free environment, and health- care outreach also

contribute. Infections result in loss of appetite, impaired absorption and utilisation of nutrients, particularly micronutrients. Environmental xenobiotics also impair MN utilisation. The present paper specifically focuses on feasible approaches and research needed to improve dietary access to MN.

## Magnitude of the Problem of Micronutrient Deficiencies in India

Among the MN deficiencies, iron deficiency anaemia (IDA) is the most serious public health problem[2,3,4]. Estimates of IDA in women and children have varied from 50-70%; pregnant women being particularly susceptible. Iodine deficiency disease (IDD) is another worrisome public health problem[3]. Though, its magnitude has declined in recent years after the introduction of iodised salt, the problem still persists, and not confined to the Sub Himalayan regions as earlier thought. Fortunately, some of the severe vitamin-deficiency diseases such as beri beri (thiamine-vitamin B1 deficiency), pellagra (niacin deficiency), and scurvy (vitamin C deficiency) have disappeared. Blindness due to vitamin A deficiency and rickets due to vitamin D deficiency remain as clinical rather than public health problems. However, milder clinical manifestations and biochemical (sub-clinical) evidence of these deficiencies is rampant. Also osteoporosis in adults, particularly women after menopause due to calcium and vitamin D deficiency is common.[5]

***Functional significance of sub-clinical MN deficiencies needs to be established.***

## Dietary Aetiology of MN Deficiency in India

Repeated diet surveys done by the National Nutrition Monitoring Bureau (NNMB) (National Institute of Nutrition, ICMR) in 9 states of India and some other surveys, indicate, the following[2].

Cereal-pulse based Indian diets are qualitatively deficient in micronutrients particularly iron, calcium, vitamin A, riboflavin and folic acid (hidden hunger), due to low intake of income-elastic protective foods such as pulses, vegetables particularly green leafy vegetables (GLV), fruits, and foods of animal origin. In recent years, there has been substantial erosion of area under cultivation of coarse grains and millets and share of these nutritious grains in total cereals produced and consumed[6].

More than 70% of preschool children consume less than 50% RDA of iron, vitamin A and riboflavin.

Within a family dietary deficits are more marked for preschool children due to inequitable distribution of food. This is because of lack of awareness of children's nutritional needs, and inability of child to articulate. While income cannot be blamed if the family has enough food for adults, time constraint on the mother who has to go out to work to supplement the family income, is a factor.

In recent years concern has been expressed about the inadequate intake of other micronutrients such as zinc, vitamin D, calcium and vitamin $B_{12}$.

***More research is needed to establish the extent of dietary deficiency and requirement of these nutrients.***

## Consequences of Micronutrient Deficiencies

Apart from human suffering due to morbidity and mortality, malnutrition in general and MN deficiencies in particular have a high economic cost. `Productivity losses due to poor nutrition are estimated to be more than 10% of lifetime earnings for individuals, and 2-3 % of GDP to the nation. Cost of treating malnutrition is 27 times more than the investment required for its prevention'[7]. According to a panel of Nobel laureates, of the top 10 priorities selected for advancing global welfare using methodologies based on the theory of welfare economics, in Copenhagen Consensus, 2008, 5 were in the area of nutrition – micronutrient supplements, micronutrient fortification, biofortification, de-worming and other nutrient programmes at school and community level[8]. These are also needed to achieve the millennium development goals.

### *Iron Deficiency Anaemia (IDA)*

Moderate and severe IDA adversely affects immunity (resistance to fight infections), cognitive and motor development, physical performance (and hence productivity) and reproductive health: (premature birth, low birth weight and perinatal mortality)[9,10]. It is estimated that anaemia is the direct cause of maternal deaths in 20% and contributory cause in another 20%. Apart from dietary deficiency, helminthic infections, inhibitors of iron absorption, in the diet and repeated pregnancies (in women) also contribute.

### *Iodine Deficiency Disorder (IDD)*

Goitre is the clinical manifestation of iodine deficiency disorder. The functional consequences are: permanent brain damage, (cretinism, - mental retardation, and deaf mutism), reproductive failure, and decreased child survival. Milder deficiency also adversely affects mental development[9,10].

### *Vitamin A Deficiency*

The earliest ocular manifestation of vitamin A deficiency (VAD) is night blindness, and Bitot spots on the white of the eye. Severe vitamin A deficiency leads to keratomalacia (ulceration and sloughing of the cornea) and total blindness. Though kerotamalacia is no longer a public health problem, night blindness is prevalent particularly in pregnant mothers and subclinical deficiency (low Serum levels of Vitamin A), is still encountered. In addition to the ocular manifestations, vitamin A

deficiency has been shown to cause growth retardation, decreased resistance to infections, and even death[9,10]. Opinion regarding efficacy of vitamin A supplementation in reducing mortality even in populations with sub-clinical vitamin A deficiency is however divided[11,12,13].

## B-Complex Deficiencies

Though there is marked dietary, biochemical and clinical evidence of riboflavin (vitamin $B_2$) deficiency (metabolically a very important vitamin), it has not received adequate attention because its deficiency is neither a killer nor a crippler. Impaired psychomotor performance in school children and adults and impaired reproduction in animals associated with riboflavin deficiency has been reported[9.10,14]. There is evidence of dietary and biochemical folic acid deficiency in India[9,10]. It can cause megaloblastic anaemia due to impaired red cell maturation. Folic acid deficiency has also been implicated in congenital malformation (neural tube defects), Folic acid supplementation in early pregnancy or even pre-pregnant state has been shown to prevent it. Folic acid deficiency leads to raised levels of serum homocysteine – an independent risk factor for cardiovascular disease (CVD)[9,10,15,16]. Fragmentary evidence suggests that Indians do tend to have high levels of homocysteine which responds to treatment with folic acid[16]. Till recently, vitamin $B_{12}$ deficiency was not considered to be a problem in India since its daily requirement is only 1 microgram. However, reports of vitamin $B_{12}$ deficiency in developing countries like India and its link with homocysteinaemia, besides megaloblastic anaemia, have started appearing[17]. Both folic acid and $B_{12}$, besides vitamin $B_6$ and $B_2$ are required for homocysteine metabolism.

***In view of the rising incidence of CVD in India, B- complex vitamin deficiency needs to be taken more seriously and its link with homocysteinaemia and CVD needs to be investigated. Research is also needed to examine the role and dosage of folic acid for prevention of neutral tube defects- which are not uncommon in India. A balance of folic acid with vitamin $B_{12}$ has to be ensured.***

## Vitamin D Deficiency

Main function of vitamin D is in bone calcification by facilitating calcium absorption and maintaining blood calcium levels. Since generation of vitamin D in the skin from its precursor 7-dehydrocholesterol is through exposure of skin to sunlight, adequacy of vitamin D in a tropical country like India was assumed. However, recent studies suggest existence of vitamin D deficiency in all age groups in India. As mentioned earlier, osteoporosis associated with calcium and vitamin D deficiency is common in post-menopausal women. Low levels of vitamin D are also associated with chronic diseases like certain malignancies, and chronic inflammatory and autoimmune diseases like type 1 diabetes, and impaired resistance to infections[5,9,10]. However, according to a recent review "Health—benefits often reported in the media—were

from studies that provided often mixed and inconclusive results and could not be considered reliable".[5]

***Research is needed to determine the dietary requirement of vitamin D to ensure adequate vitamin D status.***

### *Vitamin C Deficiency*

Vitamin C is a powerful antioxidant. Dietary vitamin C deficiency does exist, but severe clinical manifestation (scurvy) has become rare. Vitamin C is an iron absorption promoter and hence its deficiency can contribute to IDA. Antioxidants delay degenerative diseases[9,10].

### *Zinc Deficiency*

Zinc is essential for growth and development. Zinc supplementation has been reported to help linear growth, reduce severity and duration, of diarrhoeas, and respiratory infections and reduce child mortality.[10]

***The magnitude and consequences of zinc deficiency in India need to be determined. For the purpose suitable indicators have to be developed to assess zinc deficiency.***

## Strategies for Increasing Access to Micronutrients — Current Response and Research Opportunities

Basically there are four types of approaches to augment MN intake. 1) Pharmaceutical supplements, 2) Food fortification 3) Biofortification and 4) Food-food fortification (dietary diversification).

## Micronutrient Supplementation

### *National Nutritional Anaemia Control Programme (NACP)*

In this programme supplements containing 100 mg of elemental iron + 500 µg folic acid are given to pregnant women for 100 days during pregnancy; 20 mg elemental iron and 100 µg folic acid are given daily to preschool children for 100 days in the year.[9,10]. Recently adolescent girls have also been included as part of the life cycle approach with same dose as pregnant women, and weekly once administration throughout the year. Unfortunately despite scientific basis for the programme, iron-folic acid supplementation has failed to have an impact on the incidence or severity of anaemia, allegedly due to 1) lack of awareness regarding its importance and consequently poor compliance and 2) poor outreach in a vast country like India. NFHS 3 survey shows less than 20% full compliance in pregnant and lactating women.[4] 3) Uniformly giving one tablet of IFA (which is meant for preventing anaemia in non-anaemic women) regardless of the severity of anaemia.

Screening of all pregnant women for anaemia and treatment of anaemic women besides the prophylactic treatment with iron, folic acid has been recommended to reduce the prevalence and severity of anaemia in pregnancy. .

## *Suggestions for Research to Improve NACP*

Public-private-NGO partnership may have a role in improving the outreach. Absorption of non-haeme Iron from the diet is only 3-5%. The challenge is to translate filling of iron stores in to improvement in haemoglobin.

***Research is needed to find out socio-cultural, behavioural factors and administrative bottle neck to improve the efficiency of NACP.***

All pregnant women should get Hb estimation done using reliable method and anaemic women treated with appropriate route and dose of iron, folic acid.

Children coming to hospital for any illness and undernourished children should be screened and those found anaemic should be appropriately treated.

Prevalence of iron, folic acid and $B_{12}$ deficiency in non anaemic and anaemic pregnant women in different regions of the country should be assessed to find out if the current practice of prescribing iron and folic acid without $B_{12}$ is appropriate.

***Efficacy of present regimen of giving uniformly one tablet of iron –folic acid needs re-evaluation and replaced with treatment after screening.***

Since nutrients, besides iron and folic acid, are also involved in haemoglobin synthesis/formation of red blood cells/absorption of iron, inclusion of MN like vitamins $B_{12}$, C, $B_2$, and zinc may improve the efficacy of the oral supplements.

***Clinical research in a hospital setting with appropriately worked out dose and schedules for multi-vitamin supplements Vs IFA supplements should be conducted.***.

## *Massive Dose Vitamin A Supplementation to Prevent Nutritional Blindness*

In this programme children between 6-60 months are given 200,000 IU of vitamin A, every six months as prophylactic dose. The rationale is: vitamin A being fat soluble, is stored in the liver and a massive dose would ensure adequate storage to last for at least 6 months**.** This programme also suffers from the infirmity of the other programmes *viz*., poor outreach, inadequate and irregular supplies. As mentioned earlier the severity of vitamin A deficiency has reduced despite inefficient operation of this programme and several eminent nutrition scientists have raised doubts about its continuation[11,12,13]. However, as of now, this programme should continue in areas where vitamin A deficiency is a public health problem (incidence of Bitot spots more than 0.5%).

According to the Annual Report of Micronutrients Initiatives India, an International Non Government Organization, out of 32 Million US Dollars available

in the Annual Budget 2009-2010, more than 20 Million US Dollars were spent on Vitamin A Procurement and Interventions. A meager sum of 2.5 Million US Dollars was spent on Iron interventions (Umesh Kapil, personal communication). Children with VAD should be identified and should be administered VA. The present Universal VAS approach needs to be reviewed.

***There is need for operation/translational research to improve efficiency of the programme***

## Food Fortification

### *Iodised Salt*

Food fortification is a powerful method of reaching out a deficient nutrient to populations, provided the vehicle used for fortification is consumed by the poorest of the poor. In India salt is the only such vehicle and it has been effectively used for reaching out iodine. This is one successful programme in the country[3,9], but its efficiency has to be improved in terms of stability of iodine in the salt, pricing, and outreach. Private companies tend to seek easy urban markets even if the problem is more acute elsewhere.

### *Iron Fortified Iodised Salt (IFIS, also called Double Fortified Salt-DFS)*

This technology was developed by the National Institute of Nutrition, Hyderabad to address the dual problem of iron and iodine deficiency.[9,10,18]. Government order for its production has been released. Its efficacy has been tested in small scale studies. ***Systematic programme for scaling up is needed to examine the effectiveness of DFS in preventing iron and iodine deficiency and replacing iodised salt with IFIS. Evaluation of DFS should be done by an independent agency rather than ICMR.***

### *Iron Fortified Wheat Flour (Atta) and Rice*

Since staple grains are consumed in substantial quantity, their fortification makes sense. In some countries wheat flour is fortified with iron and other micronutrients. Doubts have been raised about bio-availability of iron from wheat 'atta' because of high phytate (inhibitor of absorption) content. The inhibitory effect of phytate may be bypassed by some potential compounds like Na-Fe-EDTA and or enzyme phytase. The higher cost of this salt may be off-set by better bioavailablity and hence lesser dose of fortification.

For more than a half the population in India, rice is the staple. Fortification of rice has been tried by mixing fortified extruded grains from rice flour with rice (Ultra rice). More research is needed to make this technology cost-effective and acceptable.[19]

***Programmatic studies are needed to examine the effectiveness of fortifying cereals with iron.***

## Fortification of Cereal Products with Folic Acid

In many countries, cereal products are fortified with folic acid to reduce the incidence of neural tube defects. Folic acid fortification, perhaps along with vitamin $B_{12}$ may also reduce serum homocysteine levels.

***In view of the rising incidence of CVD in India, this strategy needs to be researched.***

## Fortification of Oil with Vitamins A and D

Gujarat has taken the initiative. ***Impact studies are needed.*** *Fortified oil should be packed in dark bottles to cut off UV radiation, and prevent oxidation of vitamin A*

Vehicles like sugar or soya sauce used in some countries are not suitable for India.

## Fortification of Food for Supplementary Feeding

India has large feeding programmes like supplementary feeding of preschool children through ICDS and school children through Mid Day Meal. Opinion of nutritionists is divided about fortifying these foods with MNs – sprinklers (micronutrient powder- MNP), spreads.

***Well planned field research to examine efficacy, feasibility and cost of fortification vs. enrichment with MN rich foods, of meals for supplementary feeding need to be undertaken. Impact of Golden rice rich in provitamin A, ultra rice rich in iron and other MN and red palm oil in feeding programmes needs to be researched for feasibility, acceptability and cost effectiveness.***

Food fortification is suitable only for prevention of MN deficiencies and not for treating severe forms of the disease. Food fortification programme for country should consider the Recommended Dietary Allowances (RDA) of different nutrients for Indians, the types of foods to be fortified, nutrients to be added and the percentage of the RDA to be supplied through fortification etc. to avoid excess intakes by the rich and deficient intakes by the poor. Fortified foods should be affordable by the poorest of the poor, and reach the unreachable in a vast country like India.

## Bio-fortification

Enriching germplasm with MNs through conventional breeding methods, molecular breeding and genetic engineering is a promising method for increasing dietary access to MNs. Bio-fortification is a sustainable intervention being a seed- based technology. There is no recurring cost, once the varieties are developed and adopted. It can benefit the farmer as well as the consumer if the cost of seed is kept low and not exploited by seed companies. Bio-fortified plants grow better. Potential nutritional impact of iron biofortificaion in India seems to be encouraging.[20] "The Harvest Plus: bio-fortification challenge programme is an interdisciplinary, global alliance of research and implementing institutions[21,22]. India is part of this. It

includes: β carotene (pro-vitamin A)- rich sweet potato, and cassava, zinc and iron–rich rice, wheat, maize, pearl millet, and beans. DBT network project on bio-fortification of rice, wheat and maize is currently being implemented by ICAR Institutions and state agriculture universities and National Institute of Nutrition. Golden Rice rich in pro-vitamin A; high- iron rice (high ferritin gene from mangrove); are examples of transgenic technologies."

For conventional breeding or molecular breeding to improve the MN content of foods, sufficient within species diversity with appropriate gene pool would be necessary. Also this approach is slow. GM route with genes from other plant species, preferably edible varieties, is faster and with suitable safe guards regarding safety to health, protection of biodiversity, and cost; is a useful option for a country like India While the conventional strategies of food fortification and plant breeding to improve nutritional quality should be pursued, the GM technology despite some concerns needs to be vigorously investigated. This technology has received support from many science academies of the world including Indian academies.

## Food–Food Fortification—Dietary Diversification

The problem of MN deficiency can to a great extent be addressed by encouraging dietary diversification and household access to MN-rich foods.

Overall emphasis of agriculture, horticulture and livestock breeding has been to ensure calories, income and export. MNs are not on the antenna of agriculture planning. Decentralised planning to ensure district, village and household level adequacy of MN- rich foods is required. India being a vast country, long distance transport of perishable foods like vegetables and animal products may not be feasible. Promotion of homestead gardens even in urban areas, with emphasis on MN- dense varieties, back- yard poultry, dairy, fish ponds etc is needed.

***Operation research to study the impact of such a strategy needs high priority. Farm-based approaches are low-cost, and sustainable if the community is empowered.***

While it may be difficult to meet the requirement of some nutrients like iron and riboflavin through low-cost diets, there is ample supply of β carotene (pro-vitamin A) in nature in green leafy vegetables and yellow orange fruits and vegetables. This wealth needs to be exploited through education and advocacy. Low bio-availability of beta carotene is an issue. Food habits may be hard to change.

***Research is needed to establish the factor for conversion of β carotene to vitamin A and improve its bioavailability. Red palm oil is an important source of β carotene and can be used in supplementary feeding programmes if supply and acceptability can be assured.***

Absorption and utilisation of micronutrients is influenced by competition between nutrients, (particularly minerals and trace elements), and other biotic

(microorganisms, helminthic) and a-biotic (chemical agents like phytates, tannins, xenobiotics etc).

***These influences have to be researched to improve utilisation of dietary MNs. Treatment with phytases and tannases needs to be considered.***

**Bioavailability studies to examine the interaction within nutrients, and between nutrients and promoters, inhibitors and xenobiotics (biotic and abiotic), have to be planned.**

## Enhanced Production to Consumption of Millets and Pulses

MN rich coarse grains and millets are being forgotten. They are referred to as orphan grains, but with the threat of global warming, they may well be the grains of the future. There is 2-3 fold gap between optimal productivity of millets and farm-level productivity. Apart from being high in proteins, pulses are also rich in MN. Their production and consumption is on the decline.

***Productivity of these grains has to be increased through research and robust extension effort. Agriculture research needs to give high priority to millets and pulses – a production to consumption strategy.*** Some of the World Bank funded National Agriculture Innovation Projects (NAIP) are attempting to do that.

## Plant Foods as Speciality Foods for Protection against Chronic Diseases

***This is a vast field for research*** since plant foods are rich in health giving phytochemicals-nutraceuticals. Some nutrients like vitamin C, E, Se also have antioxidant properties.

## Economic Logic

World Bank has compared the benefits of MNs (iron) supplementation vs. Food fortification in terms of 1) cost per life saved, 2) productivity gained- a measure of efficient use of resources and defined as least cost discounted method of reducing clinical deficiency in the population and 3) social benefit cost- DALY or healthy life years saved. For saving life at least cost, targeted iron supplementation to pregnant women is more effective than iron fortification of flour or other staple. However, for enhanced productivity delivered by a programme and social benefit cost, iron fortification is most cost effective. (For details see, Hunt[23])

***Similar analysis is needed in the Indian context. Farm-based interventions are believed to have high benefit-cost ratio in terms of economic cost. They also help the farmer and empower the community.***

## Food Analysis

India is rich in biodiversity with lots of local foods with potential benefits in terms of MN as well as health-promoting phytochemicals. Food analysis labs equipped to do co-ordinated MN analysis with proper quality control should be set up in agriculture universities and home science colleges which have the expertise and ***country-wide research programmes to analyse local foods and identify MN rich foods should be started so that their production and consumption can be enhanced.***

## Food Storage and Processing

Almost 30% of farm food perishes due to lack of storage facilities and value addition. ***Development of suitable storage structures not only for grains but also for vegetables, fruits and animal products and promoting those which are already available is urgently needed. There are indigenous time-tested traditional technologies for storage. Those have to be re-discovered and promoted***.

Value addition should not take away food from the poor. ***Both, high-end and low-cost, processed foods need to be developed with public private partnership, with the triple objectives of reducing wastage, generating employment and enhancing nutrition value and security.***

## Bioavailability and Stability of Micronutrients in Processed Foods

While minerals are reasonably stable during processing, vitamins, particularly vitamins A and C are sensitive to light and heat. Microencapsulation is done to increase the stability, but that increases the cost. Low-cost technologies to increase the bioavailability and stability of MNs in processed foods are needed to make processed foods accessible to all sections of the society.

## Nutrition Security and Climate Change

Rise in temperature due to climate change is associated with increase in atmospheric carbon dioxide. While the latter helps to increase plant growth if there is enough supply of other nutrients in the soil, in tropical climate, further temperature rise has an adverse effect. It is suspected that apart from plant growth, climate change may also affect the nutrient composition (protein and minerals) in foods. No information is available on vitamin content of foods and climate change.[24]

***Impact of climate change on productivity and nutrient composition of major food items in India needs to be researched.***

## Monitoring, Surveillance and Management Information System for Early Detection

India needs a robust monitoring and surveillance programme in nutrition for early identification of the problems and capacity building to tackle them in a decentralised way. For every frank case of deficiency, there are dozens of others who suffer from subclinical deficiencies which contribute substantially to human suffering, medical expenses and economic cost.

***Sensitive biochemical and functional tests to detect such deficiencies, using new knowledge of molecular and cellular biology and state of the art instruments need to be developed***

## Nutrition and Health Education

Behavioural Change Communication (BCC) programs to targeted audience can improve both nutrition and health status. Nutrition education for professionals-(agriculture, medical, social scientists and others), needs to be strengthened.

***Innovative strategies need to be developed and tested not only to improve knowledge and attitudes but practices as well. Behavioural modification modules are needed. Nutrition education policy is nonexistent. Awareness among school children, teachers, consumers and women has to be enhanced. Women empowerment is essential to improve diets and health. Nutrition component of medical and agriculture curricula needs to be strengthened.***

## Conclusion

The current mindset of looking at food security only in terms of energy security has to change. Pumping cereals alone to quench hunger will not ensure nutrition and health. The goal should be to ensure a balanced diet adequate in macro- and micronutrients. Laboratory, clinical, and community (operations) -based research is needed to ensure MN security. An optimum mix of food-food fortification, (dietary diversification), biofortification, and early detection and effective treatment of clinical deficiencies needs to be worked out. Extension methodology has to be robust. Media support for creating awareness and compliance is important. The most important low-cost intervention is following WHO guidelines for breast feeding- early initiation, exclusive breast feeding for 6 months and complimentary feeding with continuation of breast feeding up to 1 year. This requires media blitz to educate the community.

## Summary Table of Recommendations for Research and Action

The following table attempts to prioritize the suggestions made as priority 1+ (very high), which has evidence-based strength and need immediate action and scale up. Priority 1, (high) has some evidence, but needs more research. Priority 2 (moderately high) needs more evidence and research inputs. Research areas have been grouped under: 1.Translational and operation research other than agriculture, 2 Laboratory, clinical and controlled field research (other than agriculture), 3. Agriculture. The term agriculture includes horticulture, livestock and fisheries. Nutrition being a complex and multidimensional subject, inputs are needed from various areas and hence the wish list is long.

| S No. | Research area | Type of Research | Agency | Priority |
|---|---|---|---|---|
| **Translational, Operation Research other than Agriculture** | | | | |
| 1 | Improve the efficiency of micronutrient supplementation programmes- NACP, Massive dose vitamin A supplementation , iodised salt distribution | Multi-dimensional investigations to find out administrative and outreach bottlenecks and socio cultural, behavioural factors<br><br>Efficacy of present regimen of giving uniformly one tablet of iron –folic acid needs re-evaluation and replaced with treatment of anaemia with higher dose after screening. | Health ministry should contract it out to a good management research group<br><br>ICMR | I+ |
| 2 | Replace iodised salt with iron fortified, iodised salt (double fortified salt) | Study the effectiveness, and acceptance in a scaled-up programme | ICMR, Ministry of health, Ministry of civil supplies, private sector, home science colleges | 1+ |

| S No. | Research area | Type of Research | Agency | Priority |
|---|---|---|---|---|
| 3 | Nutrition monitoring, surveillance and management information system(MIS) | Put in place effective system for early detection of nutritional problems in the community | Ministry of health in collaboration with ICMR, Dept. of women and child development and Department of space, home science colleges | I+ |
| 4 | Infant and child feeding-promotion of breast and complimentary feeding according to WHO norms | Large scale awareness programme through media blitz | Ministry of health, HRD, I&B, Space, home science colleges etc | I+ |
| 5 | Fortification of cereals-wheat flour and rice with iron | Investigate the effectiveness, outreach, and cost benefit ratio. | ICMR, CSIR, DST, DBT, Ministry of health, Ministry of food processing industries, international agencies | I |
| 6 | Nutrition education, extension and training | 1Strengthen nutrition component of medical and agriculture curricula.<br>2. Nutrition education at all levels | Ministries/depts. of health, women and child development, agriculture, human resource development, I & B, space | I |
| 7 | Fortification of oil with vitamins A and D- Gujarat experiment | Investigate the effectiveness/ cost benefit ratio, stability of the fortificants. Learn from Gujarat | Gujarat state government, ICMR, ministry of health, | II |
| **Laboratory, Clinical and Controlled Field Research other than Agriculture** | | | | |
| 1 | Multi nutrient pill containing besides iron and folic acid, zinc, and vitamins $B_{12,}$ $B_2$ and C for anaemia prophylaxis | Controlled laboratory and clinical trials to examine the efficacy, and cost benefit, | ICMR | $I^+$ |

| S.No. | Research area | Type of Research | Agency | Priority |
|---|---|---|---|---|
| 2 | Bioavailability studies to examine interaction within nutrients and between nutrients and promoters and inhibitors- biotic and abiotic | Select research studies at institutional level | ICMR,ICAR,CSIR, DST,DBT | I |
| 3 | Bioavailability of beta carotene from plant foods-Conversion factor for beta carotene to vitamin A in Indian context. Effect of vitamin A deficiency | Controlled laboratory and clinical studies | ICMR, CSIR, DBT | I |
| 4 | Role of B-vitamins deficiencies in aetiology of raised levels of homocysteine–an independent risk factor for CVD. Genetic predisposition | Controlled laboratory and clinical studies | ICMR, CSIR, DBT | I |
| 5 | Development of non-invasive methods for assessing MN status. eg. Dry blood spot method | Laboratory studies in select well equipped institutions. | ICMR,ICAR,CSIR, DST,DBT | I |
| 6 | Ready to cook, MN fortified foods suitable for institutional meals-ICDS, MDM, and homes. Comparison with food-food fortification with vegetables, fruits and products like red palm oil | Field studies to compare chemical fortification with food- food fortification | ICMR,ICAR,CSIR, DST,DBT, Ministry of food processing industries, NGO, Home science colleges | II |
| 7 | Assessment of the magnitude of deficiency and requirement of less-recognised MN like zinc, vitamin $B_{12}$, an vitamin D by developing appropriate laboratory tests | Laboratory studies in select well equipped institutions. | ICMR, CSIR, DST,DBT | II |

| S No. | Research area | Type of Research | Agency | Priority |
|---|---|---|---|---|
| 8 | Functional significance of subclinical MN deficiencies | Laboratory/clinical studies in select well equipped institutions. | ICMR, CSIR, DST,DBT | II |
| 9 | Plant foods containing nutraceuticals as speciality foods | Laboratory and clinical studies in select institutions. | ICMR, CSIR, DBT,DST | II |
| 10 | Bioavailability and stability of MN in processed foods | Laboratory and field studies | CSIR,DST,DBT Ministry of food processing industries | II |
| | **Agriculture, (including horticulture livestock research)** | | | |
| 1 | Increased production to consumption of pulses, coarse grains and millets | Agriculture extension work to bridge the productivity gap where products exist.<br>Research to increase productivity | ICAR, Central and state agriculture universities, Home science colleges, ICMR | I+ |
| 2 | Food- food fortification-dietary diversification through decentralised agriculture planning, including homestead production. | Field trials to examine the impact of village- level and household production of vegetables, fruits, dairy, and poultry, fish using improved varieties, on household food security. | ICAR, Central and state agriculture universities, Home science colleges, ICMR, NGOs | I+ |
| 3 | Biofortification using conventional and molecular breeding- | Research and development. Scaled up field trials with products available. | DBT, ICAR, Central and state agriculture universities | I+ |
| 4 | Genetic engineering to develop micronutrient - enriched food grains, vegetables and fruits | Research for health and environment safety etc<br>Develop new products. | ICAR, Central and state agriculture universities | I |
| 5 | Golden rice to improve vitamin A nutrition | Validation studies | ICMR,ICAR,DBT | I |

| S No. | Research area | Type of Research | Agency | Priority |
|---|---|---|---|---|
| 6 | Development of storage and packaging methods to preserve the MN content of foods, and prevent infestation. | R&D work, identification of time tested traditional methods. Promotion of methods already developed | ICAR, Home science colleges | I |
| 7 | Analysis of local foods for micronutrients and health promoting phytochemicals. (These can also be resource for molecular breeding studies) | A large scale multi-centric effort using quality control at reference laboratories | Select institutions from ICAR, agriculture universities, home science colleges with NIN and CFTRI as reference laboratories | II |
| 8 | Impact of climate change on productivity and micronutrient content of staple foods | Controlled simulation studies in agriculture institutions and select laboratories | ICAR, DBT, Agriculture universities | II |

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