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Review Article

Strategies to Combat Micronutrient Deficiencies: A Review

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ABSTRACT

Over 3 billion people all over the world are affected by micronutrient deficiencies especially in developing countries. Individual human potential is hindered by micronutrient deficiencies adversely affecting national, social and economic development. Various short and long term strategies have been used in different countries to combat micronutrient deficiencies. Feeding programmes often fail to address problems of micronutrient deficiency as budgets do not allow micronutrient rich foods to be included in meals. Recent technological advancements include various strategies to alleviate micronutrient deficiencies like fortification, bio-fortification and genome wide association studies which lead to improvements in micronutrient content of foods. Every human being requires essential micronutrients to sustain their lives and these micronutrients are obtained from diet only. Food based strategies require an innovative approach to promote dietary diversification, decrease nutritional losses and increase nutritional bioavailability. Efforts by many developing countries have shown that food based strategies are cost effective and a sustainable solution for alleviating the problem of micronutrient deficiencies in populations. Strategies to alleviate the problem of micronutrient deficiency would essentially fail to make an impact unless adequate attention is given to preventing communicable diseases like diarrhoea, reducing morbidity and improving basic health care facilities. There are several advantages with booming food based strategies like improving nutritional well being of individuals, incomes of the individuals, providing access to and availability of a various micronutrient-rich foods which further will lead to improved micronutrient status of not only individuals but as well as for the community also on the whole.

Key words: micronutrient deficiencies, short term strategies, long term strategies, food based strategies, dietary diversification, food fortification, bio-fortification

INTRODUCTION

In spite of various developments and improvements in the field of child health and nutrition, malnutrition still remains one of the major public health problems of the 21st century especially in developing countries. [(1)] Approximately 6.9 million children under 5 years of age died worldwide in the year 2011 because of under nutrition, due to increased vulnerability to diseases. [(2)]

Micronutrient malnutrition especially deficiencies of vitamin A, iodine, and/or iron deficiency is globally affecting over 3 billion people mostly women, infants and children in resource-poor families. [(3,4)] Micronutrients like vitamin A, vitamin C, folic acid, vitamin B12, riboflavin, iron, zinc, and selenium, have immune-modulating functions and thus influence the vulnerability of a host to infectious diseases followed by the course and result of such

diseases. [5] Vitamins A and D, iron, iodine and zinc deficiencies in developing countries aggravate the disease burden which results in higher mortality rate and many health problems. [6] Vitamin A, iron and iodine deficiencies are among the major public health problems of the world today while zinc, folate, and the B vitamins deficiencies are also being recognized as public health concerns. [3] Efforts are going on to reduce the number of the children suffering from malnutrition in developing countries, but still these deficiencies continue to affect a large number of children resulting in poor health, low cognitive performance and efficiency. Following review has been written to explain in detail about various micronutrients and strategies to combat micronutrient deficiencies.

Micronutrients of concern

Vitamin A

Vitamin A has many functions in the human body, including growth, vision, epithelial cell differentiation, immune function, and reproduction. The retinal form is involved in vision, whereas retinoic acid is involved in growth and cellular functions. Retinol is also responsible for maintenance and differentiation of epithelial tissues and reproduction. [7]

Globally, about one third of children in developing countries are suffering from vitamin A deficiency. Vitamin A deficiency (VAD) has been considered as a major factor responsible for deterioration of the economic and health status of the communities of lower-income South Asian countries. [8] Severe VAD leads to xerophthalmia, the most common cause of preventable blindness among children. About 91.5 million of preschool children residing in South East Asia had serum retinol concentrations <0.70 μmol/L, i.e. <20 μg/dL. Further, night blindness in preschool children was the highest in South-East Asia (82.4%) compared to a very low prevalence in Europe (1%) and almost nil (0%) in America. [8] Preschool children are going through a period of rapid growth, physical and mental development, and have increased needs for the micronutrients which are lost due to worm infections. Most common STH reported are roundworms in preschool children which lead to considerable vitamin A mal-absorption. [9] Deworming is therefore an accepted intervention especially in developing countries. [10]

Iron

Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues.

Globally Iron deficiency anemia (IDA) is the most common prevalent nutritional problem which has an effect on more or less all age, sex and physiological groups. [11] The estimated global anaemia prevalence is found to be 24.8 %, affecting 1.62 billion people. Anemia is caused not only by efficiency of iron, but is also associated with other nutrient deficiencies, like vitamin A, B6 and B12, riboflavin, and folic acid. Nutritional status especially iron status gets aggravated due to parasitic infestations. Hook worms are the most harmful worms followed by whip worms as these cause blood loss. [12] Deworming done at regular intervals is considered to have major effect on nutritional status, including iron status. For example, in Tanzania, deworming has shown a significant effect on nutritional status and the extent of anemia in children less than two years old. [13] Due to iron deficiency work performance of school children is affected and large proportions of maternal deaths are linked to anemia in pregnancy. [14] IDA leads to serious consequences on productivity and cognition among children signifying the need for immediate actions to be adopted to decrease

iron deficiency in South Asian developing countries. [15]

Iodine

The major role of iodine in the human body is in the synthesis of thyroid hormones by the thyroid gland. Iodine deficiency affects all stages of human life, from the intra-uterine stage to old age. Approximately 740 million people are affected by goiter in the world and more than 2 billion are at risk of Iodine deficiency disorder (IDD). Globally 13% of population has been affected by IDD making it a public health problem in 130 countries. [16]

Zinc deficiency

Deficiency of Zinc affects nearly half of the population globally. It has been reported that 1 to 13% of the population in Europe and 68 - 95% in North America have low dietary intakes of zinc. Around 61 % of the children from developing countries are at the risk of low zinc intake and therefore they are susceptible to zinc deficiency. [17]

Frank clinical signs of deficiency of different nutrients such as thiamine, niacin and vitamin C have decreased, but vitamin D deficiency has emerged as a problem of public health significance. [18]

Approaches for tackling micronutrient deficiency

Micronutrient deficiencies among children and women during their reproductive years hinder individual human potential and thus adversely affecting national, social and economic development. Presented here is an evaluation of the various long and short term strategies which have been used in different countries to tackle the problem of micronutrient deficiencies.

Short Term Strategies

1. **Food Supplementation**

The worldwide problem of micronutrient malnutrition is the consequence of inability of food systems to provide enough micronutrients to meet the nutritional needs of the population. For sustainable growth and development in developing countries the problem of malnutrition of needs immediate attention, and food supplementation is a short term strategy to combat deficiencies.

The Mid Day Meal (MDM) is the world's largest school feeding programme reaching out to about 104.4 million children in 1.2 million schools across India. [19] An evaluation of this program indicated that it benefitted children in terms of their increased enrollment and attendance in schools. [20] Shalini et al. [21] have stated that MDM reduced the number and the degree of malnourishment in the state of Bengaluru.

Integrated Child Development Service Programme (ICDS) is a unique programme currently run in India under which a package of integrated services consisting of supplementary nutrition, immunization, health check up, referral and education service are provided to the most vulnerable groups i.e. children up 6 years of age and expectant/nursing mothers, through a common focal point called *Anganwadi* (the courtyard centres) in each village/urban slum. [22] Even in the most-developed nations, there are hungry children who have been helped by school meals. World Food Programme (WFP) provides food assistance worldwide in 169 countries and to 368 million children. In low income countries the overall average coverage of these programmes is the lowest (18%) and in lower-middle-income countries it is 49%, with India at 79 %. Reviews of 18 trials from five continents reported over the last eight decades have shown that school feeding programs significantly improved attendance levels and the cognitive performance in disadvantaged children. [23]

2. **Nutrient Supplementation**

Supplementation with nutrients is a short term intervention which can help in improving nutritional health but is not justifiable to use for large populations. This approach is considered to alleviate micronutrient deficiencies using the process of distribution of pills, powders or tablets for

consumption by vulnerable target groups. [24] Usually supplementation is considered to be used in the small group of populations with specific nutrient deficiencies in developed countries while in developing countries it is been highly recommended to combat chronic and acute deficiencies. [25]

Distribution of vitamin A supplements has been considered to be one of the most cost effective and successful acute intervention programs in the developing world. [24] Mineral supplements are considered to treat acute deficiency like Zn supplements rank very highly according to the Copenhagen Consensus report cost-benefit analysis. WHO and UNICEF adopted Zinc supplementation in the form of tablets or as oral rehydrated solutions for the treatment of acute diarrhea. [26]

In 1971 India was the first country to start Vitamin A Prophylaxis Programme for Prevention of Nutritional Blindness. [27] Under this programme children aged from 1 to 5 years are given a dose of 200,000 IU of vitamin A once in six months and after revision in 1991 dosage of children aged from 6-11 months became 1 dose of 100, 000 IU and of 1-5 years was 200, 000 I.U. every 6 months. [28]

A study by Semba using NFHS III 2005–2006 data showed that Vitamin A supplementation coverage decreased with age. Coverage with one dose in the past six months was 45.4% among children aged 12–23 months, as compared to 16.4% among children aged 36–47 months. [29] Similarly UNICEF's coverage evaluation survey showed that though 58% of children aged 12–23 months received one dose of the supplement, only 37% had received the dose within the past six months. [30] However, incidence of clinical VAD has significantly reduced during the last 40 years. There has been virtual urgent need for implementing a targeted approach rather than universal approach for the massive dose vitamin A prophylaxis programme. The available scientific evidence reports side effects of massive doses of vitamin A especially in children who are not deficient and resource constraints with competing priorities. [31]

National Nutritional Anemia Control Programme (NNACP) began in 1970 in India. Supplement constitutes one small tablet containing 20 mg iron and 100 µg folic acid daily for 100 days every year for preschool children which was extended in 2007 to cover infants aged 6–12 months. One big (adult) tablet per day for 100 days (each tablet containing 60 mg/100 mg of elemental iron and 500 µg folic acid) for pregnant women was recommended for women after the first trimester of pregnancy. One big (adult) tablet (containing 60 mg/100 mg of elemental iron and 500 µg folic acid) per day for 100 days was also recommended for lactating women and IUD acceptors. [32,33] A Weekly Iron and Folic Acid Supplementation (WIFS) Programme (100mg elemental iron and 500 µg folic acid) for school going adolescent girls and boys and for out of school adolescent girls has also been launched in India. The programme envisages administration of supervised weekly supplementation and biannual deworming tablets to approximately 13 crore rural and urban adolescents through the platform of government/government aided and municipal school and *Anganwadi kendra* and combat the intergenerational cycle of anaemia. [34]

Supplementation requires a partnership and long term commitment among public and private organizations and constant supervision because some people forget to take their supplements at prescribed intervals. [24] Major limitations associated with supplementation approach include high cost of resources, technological difficulties in implementation of this approach, inability of the supplements to be delivered to the target population and in proper administration of doses including frequency and timing of the doses.

Long term strategies

Long term strategies like food based approaches provide multiple social, economic and health benefits which lead to year – round availability, access and consumption of adequate amounts of nutrients.

1. **Food based strategies**

Food based strategies have the potential to address many of the concerns about both the intake and the bioavailability of micronutrients such as vitamin A, iron etc among impoverished populations. They mainly aim at increasing production, availability and intake of micronutrient rich foods, bioavailability of micronutrients in the diet and concentration of certain trace minerals and vitamins and promoters of absorption. [(35)] The promotion of food based strategies to achieve sustainable improvements in micronutrient status has been slow and these strategies have been overlooked as governments, researchers, the donor community and health oriented international agencies favour approaches which can give quick and rapid results. [(36)] Hence, a number of authors have advocated the use of food-based strategies to achieve optimal dietary requirements to combat micronutrient deficiencies. [(37-41)]

a) Dietary diversification - Consuming a variety of foods to meet nutrient requirements is referred to as dietary diversification. There is strong positive correlation between diet diversity and nutrient adequacy [(35)] and dietary diversification is considered as one of the major food based approaches. Due to organizational constraints associated with strategies like supplementation most nutritionists believe that integrating micronutrient rich foods like fruits, vegetables and livestock products into diets is the only reasonable and justifiable way of alleviating micronutrients deficiency. There is a need that local foods rich in micronutrients are recognized and attempts are made to promote the consumption of these foods.

Home gardening has been the most popular food-based strategy to increase production and intake of micronutrient-rich foods. One of the success stories is of a project undertaken by Helen Keller International and AVRDC where weekly consumption of vegetables increased in target populations as compared to the control group. [(42)] Implementation of home gardening as a strategy in South Africa led to controlling VAD to a considerable level. It was reported that nearly 719 beneficiaries of the project revealed a note worthy increase in the serum retinol level from 30 to 230 retinol equivalents (RE). [(43)] In Vietnam, a community nutrition project which involved promotion of household production of carotene-rich fruits and vegetables, fish ponds, and animal husbandry with nutrition education showed that participating mothers had a better understanding of vitamin A than mothers from the control community. [(44)] In India, a home gardening project lead to increase in learning of the signs of vitamin A deficiency as well as awareness of the importance of dark green, leafy vegetables for infants. [(45)]

b) Decreasing nutritional losses – When foods are exposed to different processing conditions, it leads to variable losses of nutrients especially vitamins. The destruction of vitamins depends on different exposure conditions like presence of oxygen, temperature, presence of light, moisture, pH and duration of heat treatment. In any of the cooking method, losses always increase with longer processing time, higher temperatures, and chopped/grinded and mashed food. Simple appropriate techniques like reducing the time lapse between pre preparation and cooking and cooking and consumption of cooked foods, cooking with open lid, and

decreasing the processing and storage time can lead to minimal losses with increased retention of nutrients. [46] Washing foods before peeling, using minimal water to cook, cutting food into big pieces, minimally heating foods and decreasing exposure to atmospheric oxygen and light by covering vessel with a lid can increase the availability of micronutrients in the daily diet.

c) Improving nutritional bioavailability through food combinations – Appropriate food processing and preparation techniques with the right food combinations can be used to enhance the bioavailability of key micronutrients from foods. Absorption of provitamin A carotenoids and vitamin A is increased by including even a small amount of flesh foods which increases the fat content in a meal. In the absence of the sufficient amount of fat the absorption of carotenoids and vitamin A is limited. [47] Some food preparation and processing methods like germination and fermentation are required to be promoted at the household level to decrease the content of inhibitors or increase the content of enhancers of absorption thus enhancing the bioavailability of minerals like iron, zinc and calcium in diets.

2. Fortification as a preventive approach

Codex Alimentarius defines fortification as a process of addition of one or more than one essential nutrients to food even if it is normally present in the food for preventing or alleviating micronutrients deficiencies among population. [48] Fortification of frequently consumed foods like oils, sugar, infant foods, cereals, milk, margarine, flours is practiced in various countries. [49] In South Asian developing countries wheat is the staple food therefore importance has been given to fortify the wheat flour with multiple micronutrients. VAD was effectively controlled through fortification of sugar in Central and South America 40 years back. Fortification of sugar with vitamin A was developed in Guatemala in mid-1970s and this study established enhanced vitamin A status in Central American countries. Success stories for elimination of VAD such as sugar fortification in Guatemala and Honduras [50] show the possibility to get rid of this public health problem through wise planning. Monosodium glutamate (MSG) fortified with vitamin A is extensively encouraged and is stated to improve breast milk, serum retinol concentrations, growth and survival of preschool children in Indonesia and Philippines. [51,52] In Brazil, oil was fortified with vitamin A and led to increase in plasma retinol and liver vitamin A stores. [53] Universal salt iodization (USI) policy was taken on for sustained elimination of IDD by the joint UNICEF/WHO Committee on Health Policy, 1994. To meet up iodine requirements of a population it was decided to add 20–40 parts per million (ppm) of iodine to salt. [54] The National Iodine Deficiency Disorders Control Programme (NIDDCP) of India is a central government-assisted programme implemented in the country since 1962. The current 91 per cent household level coverage of iodized salt in India, of which 71 per cent is adequately iodized salt, is a big achievement. [55] Reduction in anemia prevalence was seen from 42% to 30% in Indian school children who consumed salt fortified with iron and iodine for two years. At present, double fortified salt is being used in some of the supplementary feeding programs in India. [56] Foods which require mandatory fortification in different countries have been listed in the Table 1. Partnership between public, private organizations is required for successful implementation of the fortification program. Fortification of food

should complement strategies that improve diet and they should not be seen as an alternative strategy alone. [64]

Table 1:- Mandatory fortification of food with nutrients in different countries

S. No.	Nutrient fortificant	Food Fortified	Country/Region
1.	Vitamin A	Sugar	Guatemala, Honduras, Costa Rica, El Salvador, Nicaragua, Panama, Zambia, Brazil
		Dried skimmed milk for complementary food programmes	Brazil
		Skimmed milk	Guatemala
		Sterilized, pasteurized low-fat milk	Mexico
		Milk	Honduras, Mexico
		Dried milk powder	Venezuela
		Evaporated milk, condensed milk	Malaysia, Thailand, Mexico
		Filled milk	Philippines, Malaysia
		Margarine	Chile, Colombia, Denmark, Ecuador, El Salvador, Guatemala, Honduras, Peru, South Africa, India, Indonesia, Malaysia, Philippines, Turkey, Mexico
		Oil products (ghee)	Pakistan, West Africa, Brazil
		Noodles	South East Asia
		Wheat flour	Pakistan
		Monosodium glutamate	Indonesia and Philippines.
2.	Vitamin D	Dried skimmed milk for complementary food programmes	Brazil
		Skimmed milk	Guatemala
		Milk	United states, Honduras
		Sterilized low-fat milk, pasteurized low-fat milk, evaporated whole and low-fat milk	Mexico
		Dried milk powder	Venezuela
		Filled milk	Philippines
		Margarine	Chile, Colombia, Ecuador, Honduras, Peru, South Africa, Indonesia, Malaysia, Philippines, Turkey, Mexico
3.	Thiamine	Wheat flour	Bolivia, Canada, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, USA, Venezuela, Indonesia
		Pasta	Chile, Guatemala
		Precooked maize flour	Venezuela
		Enriched flour	Nigeria
		Filled milk	Philippines
		Wheat flour	Australia
4.	Riboflavin	Wheat flour	Bolivia, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, USA, Venezuela, Indonesia
		Pasta	Chile, Guatemala
		Precooked maize flour	Venezuela
		Enriched flour	Nigeria
		Enriched maize meal	South Africa
5.	Niacin	Wheat flour	Bolivia, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, USA, Venezuela
		Pasta	Chile, Guatemala
		Precooked maize flour	Venezuela
		Enriched flour	Nigeria
		Enriched maize meal	South Africa
6.	Folic acid	Wheat flour	Bolivia, Canada, Chile, Colombia, Costa Rica, Dominican Republic, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Venezuela, USA, Canada, 20 Latin American Countries, Australia
		Precooked maize flour	Venezuela
7.	Iron	Wheat flour	Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, USA, Venezuela, Peru, Indonesia
		Pasta	Chile, Guatemala
		Precooked maize flour	Venezuela
		Enriched flour	Nigeria
		Biscuits	South Africa
		Salt	India
		Sugar	Brazil
8.	Calcium	Wheat flour	Guatemala, USA
		Enriched flour	Nigeria
9.	Zinc	Wheat flour	Indonesia
		Sugar	Brazil
10.	Iodine	Salt	Switzerland, Philippines, United States , Australia, India
		Wheat flour, Bread	Australia
		Biscuits	South Africa

Source: - (References: **49,51-53,57-63)**

3. Bio fortification

Bio-fortification is a sustainable intervention achievable by conventional plant breeding methods as well as modern biotechnology and genetic engineering. [65] Nutritional impact of iron bio-fortification in India seems to be encouraging. [66] Genetic engineering requires advanced biotechnology techniques to introduce genes directly into breeding varieties. This approach is formulated to improve the transport of minerals from the roots to storage tissues, to minimize the levels of anti nutritional factors which inhibit the absorption of micronutrients, to improve the uptake of minerals from soil to the roots, to improve the efficient mobilization of minerals in soil and to increase the level of absorption enhancers which can increase the absorption of the minerals in the body. [67] 'Golden Rice' is a type of cereal product which is genetically engineered to produce β-carotene (pro-vitamin A) to help combat VAD. [68]

4. Nutrition and Health Education

Combining community development programs with national programs for decreasing malnutrition with the aim of increased consumption of diverse foods can be considered as one of the best approach to alleviating micronutrient deficiencies. Behavioral Change Communication (BCC) programs for the specific target groups can lead to improvement in the nutritional and health status. Awareness has to be increased among the general public about the link between food, nutrition, health and disease. The nutritional component of agriculture needs to be strengthened by sensitizing agriculturists to promote production of micronutrient rich foods. For more than two decades now production and utilization of vitamin A rich foods has been increased through introduction of home or community gardening harmonized with novel nutrition education and social marketing strategies in various countries of South Asia. [69-70] A positive change in knowledge, attitude and practices was reported through two successful social marketing interventions using mass-media, [71] one carried out in Indonesia and the other one in Thailand. [70] In Indonesia substantial encouraging attitudinal changes were observed regarding vitamin A, and consumption of vitamin A rich foods had increased by 10 to 33 percent after two years, among the targeted group. [72] A pilot social marketing project was initiated in north-east Thailand which focused on encouraging one single vitamin A rich source vegetable – the ivy gourd and fat. This project emphasized the need to recognize and selectively disseminate dark green leafy vegetables and other β-carotene rich foods. In addition it also encouraged appropriate cooking/processing procedures in the traditional cooking, preservation, storage, marketing and improving food preparation to ensure maximum retention of the nutrient. [70]

5. Improving Sanitation

The nutritional status and health of an individual is determined by the proper digestion of food, along with the absorption and utilization of nutrients within the body. Utilization requires not only an adequate diet, but also a healthy physical environment, including safe drinking water, adequate sanitation and hygiene and timely health care interventions in case of disease. In fact, strategies to alleviate the problem of micronutrient deficiency would essentially fail to make an impact unless adequate attention is given to preventing communicable diseases like diarrhoea, reducing morbidity and improving basic health care facilities. A special effort needs to be made to break the vicious cycle of malnutrition and infection.

CONCLUSION

To summarize here we can say that recent technological advancements include various strategies to alleviate micronutrient deficiencies like fortification, bio-fortification, and genome wide association

studies which lead to improvements in micronutrient content of foods. Several strategies have been used the world over to tackle the problem of micronutrient deficiencies. Some strategies are for short term gains while others address long term issues. Food supplementation programmes often fail to address problems of micronutrient deficiency as budgets do not allow micronutrient rich foods to be included in meals. Long term strategies include dietary diversification, decreasing nutritional losses, increasing nutritional bioavailability, fortification and bio-fortification. Results of food based strategies are very difficult to analyze because outcomes are usually not quantifiable. The promotion of food based strategies to achieve sustainable development has been slow. These strategies have been overlooked by community and health oriented agencies in favour of approaches which had given quick and rapid results. However efforts by many developing countries, international agencies, non-governmental organizations (NGOs) have shown that food based strategies is cost effective and an indigenous sustainable solution for alleviating micronutrient deficiencies.

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