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The hidden hunger and strategies for its alleviation – A review

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Abstract

Micronutrient deficiencies are aptly called as hidden hunger as they do not cause any immediate disorder symptoms but do cause serious health issues eventually. The situation of malnourishment is grim as it involves significant numbers of people especially women and children from various parts of the world. Micronutrient deficiency is usually due to the lack of a balanced diet and awareness on nutritional requirements. Another lesser known culprit is natural antinutritional factors present in plant based foods which reduce the bioavailablility of micronutrients causing deficiencies. This problem can easily be overcome by countermeasures like food fortification with micronutrients or by adopting suitable food processing methods like soaking, steeping, germination, cooking or fermentation. Biotechnology can also come handy here in the form of developing food crops with reduced antinutritional factors thereby enhancing micronutrient availability. Thus developing well researched & tailored micronutrient malnutrition management strategies & their effective implementation is a need of the hour.

Key words: Micronutrients, Antinutritional factors, Hidden hunger, Malnutrition, Micronutrient malnutrition

Introduction

Malnutrition is a problem hounding many developing nations in different parts of the world. About 5 to 10% of the population in Europe & North America suffers from malnutrition but the situation is much more serious in Africa & South Asia. Micronutrient malnutrition (MM) adds misery to both developing and developed countries, probably due to lack of awareness on the importance of micronutrients in human nutrition. MM is a cause of alarm as it affects the quality of life & also the economy. MM may be caused due to several reasons like lack of food or a balanced diet, micronutrient depleted soils, improper agricultural practices & post harvest technologies, importantly lack of awareness. Though the situation sounds grim it can be overcome by suitable integrated agricultural practices, crop improvement & management systems supported by appropriate post harvest technologies & awareness programs.

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Malnutrition and Micronutrient Malnutrition (MM)

Malnutrition is globally the most serious risk factor for illness and death. According to the World Health Organization nearly 30% of people in the developing world are currently suffering from malnutrition. About 49% of the deaths among under-five children each year in the developing world are associated with malnutrition. Malnutrition affects all age groups across the entire life span but women and young children are the most vulnerable groups. In Africa and south Asia alone about 25 to 50% of women in the reproductive age group are underweight thereby increasing the chances of having underweight children (WHO 2000).

World over the number of people who suffer from micronutrient malnutrition, also called the "hidden hunger" is much higher than the 800 million people who suffer from hunger. Iodine, vitamin A, iron, and zinc malnutrition are more prevalent hence are reason for serious concern. Of the 2 billion people who suffer from iron and zinc deficiencies, most are women and children who face serious growth and developmental impairment and mortality. Half of the children under 5 do not meet the required weight and growth standards. In adult populations too malnourishment is high accounting for about 30% of the cases. Micronutrients malnutrition is as serious a problem as protein calorie malnutrition hence should be given due attention. (INSA 2011) Micronutrients like minerals & vitamins though required in small quantities are necessary for proper functioning of the body & to maintain good health. Micronutrient deficiencies along with causing specific diseases may also aggravate diseases thereby affecting health and wellbeing (Tulchinsky 2010). On the other hand some micronutrient deficiencies like iron deficiency may be aggravated by infectious diseases like malaria, TB, AIDS and parasite infections (WHO 2014). Deficiencies of vitamin A, iron, and iodine have been identified as major problems with increasing public health significance. The clinical manifestations of these nutritional deficiencies are xerophthalmia, anemia, and goiter. Micronutrient deficiencies usually donot cause severe physical impairment & mortality hence are called the 'hidden hunger'. Micronutrient deficiency though more relevant to developing countries especially with plant based diets is a challenge in developed countries as well with the increasing problem of foods with empty calories. In the developing countries MM may be due to under-nourishment or mal-nourishment whereas in developed countries over-nourishment caused by diet with empty calories.

The Recommended Dietary Allowances (RDAs) established by the Food and Nutrition Board of the National Academy of Sciences, USA was replaced and expanded with Dietary Reference Intakes (DRIs) in 1995 to provide recommended nutrient intakes for individuals and populations. The DRIs are a set of four reference values (Murphy and Poos 2002).

- Recommended Dietary Allowance (RDA): average daily dietary intake sufficient to meet the nutrient requirement of most of the (97-98%) healthy individuals.
- Adequate Intake (AI): established when an RDA cannot be determined. Recommended intake level based on determined estimates of nutrient intakes by a group of healthy persons.
- Tolerable Upper Intake Level (UL): highest average daily nutrient intake which is nontoxic to almost all individuals.
- Estimated Average Requirement (EAR): amount of a nutrient that is estimated to meet the requirement of 50% of the healthy individuals.

The DRIs are gender and life stage specific. RDAs, AIs and ULs are dietary guidelines for individuals, whereas EARs are for groups of individuals. The modified guidelines discuss in detail the factors that might possibly affect/alter it. Some of the factors discussed are the dissimilar bioavailability of nutrients from various foods, interactions among different nutrients or with drugs and supplements. The DRI for some of the vitamins & minerals for men & women over 19 years of age is indicated in Table 1.

Causes for micronutrient malnutrition

In many developing countries poor quality foods with insufficient nutrients is the major reason for dietary disorders in women and children. Malnutrition may also be due to improper or incompatible diet. Nutrient depleted soils, improper farming and agricultural practices in poorer areas of most developing countries have led to food crops with low levels of essential micronutrients. Cropping practices mostly only renew major nutrients ignoring micronutrients leading to micronutrient deficiencies (Niba 2003). Another lesser known fact is the presence of antinutritional factors that further aggravates malnutrition. Antinutritional factors are plant-based food constituents which adversely affect the bioavailability of essential nutrients by either forming complexes with them or chelating them. Some of the common antinutritional factors are: phytic acid, protease inhibitors, polyphenols, saponins etc. Antinutritional factors like phytate & tannins can negatively influence the bioavailability of some nutrients in food (Bohn et al. 2008). Most of these antinutritional factors also have a positive side to them in the form of health benefits. Unfortunately antinutritional factors aggravate malnutrition so if we wish to alleviate malnutrition, antinutritional factors should be excluded from the diet or at least significantly reduced.

Countermeasures for micronutrient malnutrition

Balanced diet can be obtained either from foods that contain high concentrations of nutrients or formulating a food type by combining different nutrients sources (fortification) or simple addition of nutrients to the diet (supplementation).The option of improving nutrient content in foods could be either through food processing or biofortified transgenic crops (Slingerland 2007). Micronutrient malnutrition can be controlled if the diet is balanced. Maintaining a complete & balanced diet is a challenge in developing countries. It is equally a challenge in developed countries too, where convenience foods with compromised nutrients have precedence over conventional foods. Some of the time tested methods that can be adopted to alleviate micronutrient malnutrition are: food fortification with micronutrients & food processing to reduce antinutritional factors are the conventional methods. Biotechnological methods are comparatively recent & less known. They are mostly crop improvement methods that facilitate increased yield, resistance to abiotic & biotic stresses, increased & improvised nutrition, reduced antinutrients & toxins. Some of these methods known to overcome micronutrient deficiency are described below.

Dietary diversification and food fortification

Dietary diversification is a consortium of strategies that involves methods to maximize the availability of sufficient amount of food along with variety of nutritious foods (FAO 1997). A varied diet provides various micronutrients thereby addressing several micronutrient deficiencies (Rodriguez-Amaya 2013) Identification of locally available foods with high amounts of micronutrients and popularizing them is foremost in these methods (Slingerland 2007). To achieve this goal it is important that the consumer is well educated about the importance of balanced nutrition. Some of the other methods could be improvement in agricultural production, encouraging home gardens, a wider range of foods along with effective food processing and preparation. Nutritional awareness and education programs through schools and public health agencies are found to make an impact. All these methods along with food fortification and supplementation are found to be of utmost importance in alleviating malnutrition as seen in the case of the German development cooperation assisted program in Malawi (BMZ 2012).

Food Fortification is defined as the addition of nutrients to food in order to introduce a nutrient(s) not previously present in the food. Nutrient augmentation to increase the level of a certain nutrient(s) already present in a food could also be done. Fortification of table salt with iodine & milk with vitamin D is common in developing & developed countries respectively (Slingerland 2007). It is one of the most prevalent methods practiced to enhance the nutritive value of foods especially processed foods. Fortification of nutrients though is a challenge in some cases; the advantage of this method is the ensured & ready availability of nutrients. The disadvantage may be with respect to the increased cost of production which could be a handicap in developing countries. Probably even the extent of absorption & assimilation of these added nutrients might raise some questions. To address some of these problems there is need for development of newer and economically better food fortifications.

Table 1: DRI for some Vitamins & minerals for individuals who are in the age group of 19 years & above (M: Males, F: Females)

Nutrient	Function	RDA/AI (µg/d)	Selected food sources
Biotin	Coenzyme in synthesis of fat, glycogen, and amino acids	M: 30 F: 30	Liver and smaller amounts in fruits and meats
Choline	Precursor for acetylcholine, phospholipids and betaine	M: 550 F: 425	Milk, liver, eggs, peanuts
Folate	Metabolism of nucleic and amino acids; prevents megaloblastic anemia	400 400	Enriched cereals, leafy vegetables, whole-grain breads & bread products, fortified ready-to-eat cereals
Niacin	Coenzyme or cosubstrate in many biological reduction and oxidation reactions, thus required for energy metabolism	16 14	Meat, fish, poultry, enriched and wholegrain breads and bread products, fortified ready-to-eat cereals
Pantothenic Acid	Coenzyme in fatty acid metabolism	5 5	Chicken, beef, potatoes, oats, cereals, tomato products, liver, kidney, yeast, egg yolk, broccoli, whole grains
Riboflavin (Vitamin B2)	Coenzyme in numerous redox reactions	1.3 1.1	Organ meats, milk, bread products and fortified cereals
Thiamin (Vitamin B1)	Coenzyme in the metabolism of carbohydrates and branched chain amino acids	1.2 1.1	Enriched or whole-grain products, mixed foods whose main ingredient is grain, and ready-to eat cereals
Vitamin A	normal vision, gene expression, reproduction, vegetables embryonic development and immune function	900 700	Liver, dairy products, fish, darkly colored fruits and leafy vegetables
Vitamin B6	Coenzyme in the metabolism of amino acids, glycogen and sphingoid bases	1.3 – 1.7 1.3 – 1.5	Fortified cereals, organ meats, fortified soy-based meat substitutes
Vitamin B12 (Cobalamin)	Coenzyme in nucleic acid metabolism; prevents megaloblastic anemia	2.4 2.4	Fortified cereals, meat, fish, poultry
Vitamin C (Ascorbic acid)	Cofactor for reactions requiring reduced copper or iron metalloenzyme and as a protective antioxidant	90 75	Citrus fruits, tomatoes, potatoes, brussel sprouts, cauliflower, broccoli, strawberries, cabbage and spinach
Vitamin D	Maintain serum calcium and phosphorus concentrations.	5 – 15 5 - 15	Fish liver oils, and eggs from hens that have been fed vitamin D, fortified milk products and fortified cereals
Vitamin E (tocopherol)	A metabolic function has not yet been identified. Vitamin E's major function appears to be as a non specific chainbreaking antioxidant.	15 15	Vegetable oils, unprocessed cereal grains, nuts, fruits, vegetables, meats
Vitamin K	Coenzyme during the synthesis of many proteins involved in blood clotting and bone metabolism	120 90	Green vegetables (spinach, salad greens, broccoli), brussel sprouts, cabbage, plant oils and margarine
Calcium	Essential role in blood clotting, muscle contraction, nerve transmission, and bone and tooth formation	1000 – 1200	corn tortillas, calcium-set tofu, Chinese cabbage, kale, broccoli
Chromium	Helps to maintain normal blood glucose levels	35 – 30 25 - 20	Some cereals, meats, poultry, fish, beer
Copper	Component of enzymes in iron metabolism	900 900	Organ meats, seafood, nuts, cereals, whole grain products, cocoa products
Fluoride	Inhibits the initiation and progression of dental caries and stimulates new bone formation	4 3	Fluoridated water, teas, marine fish, fluoridated dental products
Iodine	Component of the thyroid hormones; and prevents goiter and cretinism	150 150	Marine origin, processed foods, iodized salt
Iron	Component of hemoglobin and numerous enzymes; prevents microcytic hypochromic anemia	8 18 - 8	Fruits, vegetables, fortified bread and grain products such as cereal, meat and poultry (heme iron sources)
Magnesium	Cofactor for enzyme systems	400 -420 310 - 320	vegetables, unpolished grains, nuts, meat, starches, milk
Manganese	Involved in the formation of bone, enzymes, cholesterol, and carbohydrate metabolism	2.3 1.8	Nuts, legumes, tea, and whole grains
Molybdenum	Cofactor for enzymes involved in catabolism of sulfur amino acids, purines and pyridines.	45 45	Legumes, grain products and nuts
Phosphorus	Maintenance of pH, storage and transfer of energy and nucleotide synthesis	700 700	cream, cheese, peas, meat, eggs, some cereals and breads
Selenium	Defense against oxidative stress and regulation of thyroid hormone action, and the reduction and oxidation status of vitamin C and other molecules	55 55	Organ meats, seafood, plants (depending on soil selenium content)
Zinc	Component of multiple enzymes and proteins; involved in the regulation of gene expression.	11 8	Fortified cereals, red meats, certain seafood

Adapted from the DRI reports & established by the Food and Nutrition Board of the National Academy of Sciences, USA.

Food Processing

Food processing is the sum total of all unit operations performed in order to convert raw materials into a finished food product with better values. Most of the stable foods like cereals & pulses are minimally processed involving mostly only milling & polishing whereas the highly perishable foods like bread or a pastry are maximally processed. Foods though mostly are not processed only to extend the shelf life some of the processed foods like ultra high temperature treated milk can have a very long shelf life. Increasing the shelf life of food has a direct bearing on increased availability of food supply. Foods can also be processed to increase the availability of nutrients & decrease the content of antinutritional factors.

Some of the traditional methods of food processing are: Soaking, steeping, germination, fermentation, cooking etc. Germination of whole seeds usually activates the innate enzymes present in the seeds that help to break down complex & bound organic compounds into simpler molecules. Amylase breaks down starch in seeds into simpler sugars & phytase breaks down phytic acid an antinutritional factor into inorganic phosphorus & inositol. Fermentation is another efficient method of enhancing nutritional content & reducing antinutrients. Microorganisms used for fermentation provide the enzyme systems necessary for the catabolic breakdown of complex materials into simple molecules. Fermentation processes may be tailored to increase assimilable carbohydrates and proteins in foods thereby increasing their nutritional value and reducing antinutritional factors. Fermentaton of foods also produces antimicrobial agents like baceriocins and organic acids. (Holzapfel 2002). Bioavailability of micronutrients is an important determinant of nutritional quality and an indicator of nutritional status. Bioavailability of micronutrients from vegetarian diets may be significantly improved by simple food processing techniques like soaking, steeping, cooking, germination and fermentation. These techniques improve the bioavailability of nutrients and reduce antinutritional compounds (Hotz and Gibson 2007). Fermentation also generates a unique aroma, adds few novel nutrients and increases palatability.

Biofortification

Biofortification aims at improving nutrient density of food crops with the aid of plant breeding, agricultural management or genetic engineering (Saltzman et al. 2013). Biotechnology or breeding techniques have been used in order to improve expression & bioavailability of micronutrients. Recent agricultural research has highlighted the potential for reducing malnutrition through conventional agricultural bio-fortification. Biofortification means growing varieties that are rich in vitamins and minerals (or value addition). For example, German development cooperation is encouraging farmers in Nigeria and Kenya to grow manioc and sweet potato with a higher vitamin A content. This approach, funded by BMZ is providing large sections of both urban and rural populations with access to micronutrient rich food. The ultimate aim of breeding is to increase micronutrient content, decrease content of antinutritional factors that affect micronutrient bioavailability, or both. Few examples for biofortified crops are golden rice (rich in pro-vitamin A), high-quality protein maize (increased lysine), low–phytic acid barley, and orange-fleshed sweet potato (rich in pro-vitamin A) (Slingerland 2007). Though biotechnology is the latest entrant in the MM management system yet it has more solutions in its kitty than any other existent system. Increase in the crop/meat yield is a method which can address hunger & malnutrition. More yields would mean increased food availability. There are two basic approaches to increasing yield potential:

- Improving the overall yield by manipulating the physiology of the plant /animal.
- Develop resistance to biotic and abiotic stresses.

The disadvantage to transgenics is that they are costly and it takes time for the technology to be available to the farmers (Miller and Welch 2013).

Biofortification through Biotechnology

Increased yield through resistance to abiotic & biotic stresses: abiotic stresses like drought, salinity, temperature & biotic stresses like pathogens, pests etc adversely affect the yield. Biofortified foods with higher micronutrient density have higher absorption rate than non biofortified varieties (LaFrano et al. 2014). Genetically engineered crops that have the capacity to tolerance/resistance to these stresses are found to be more productive. For example, genetically engineered plants with insecticidal property (Bt gene), herbicide resistance (Glyphosate resistance -Roundup ready). Other applications include pest resistance in legumes, particularly towards Aspergillus flavus which produces aflatoxin in peanuts (Christou 1997).

Improved & improvised nutrition: Plants with increased expression of nutrients & production of novel nutrients thereby improving food quality are called functional foods. As in the case of golden rice where the rice plants synthesize carotene a precursor of vitamin A. Nutrition of rice has also been improvised by the expression of ferritin gene that increases iron content. Improvement in the oil content and composition of oil seeds such as canola and sunflower (Mazur 2001). Improvement in soybean oil quality includes stabilization of the unsaturated fatty acids to resist rancidity and by increasing levels of the antioxidant, vitamin E (Yan and Kerr 2002). Modifications in the starch synthesis pathway have been effected to modify ratios of amylose to amylopectin in potato and cassava starch (Visser et al. 1991 & 1997). Improving the glycemic indices of staple starchy food crops such as cassava, yams, potatoes and grains will improve their nutritional quality, and subsequently have an effect on the prevalence of attendant disease conditions like type-2 diabetes and insulin resistance. Using transgenic techniques levels of lysine in soybean and canola have been increased (Datta and Bouis 2000).

Reduced antinutrients & toxins: Low phytate corn, soybean, Modified maize in which phytates have been reduced by insertion of the degrading enzyme (phytase) gene in the product, result in greater availability of iron, despite no change in overall content of iron (Bouis et al. 2003). The increased iron absorption from low-phytic acid maize is particularly applicable in areas where maize and maize products are staples. Another possible option to increase mineral bioavailability is the use of phytase to reduce phytate content, especially during food production as it has GRAS (Generally Regarded As Safe) status for individuals of age 3 years & above (de Pee and Bloem 2008). A transgenic pig that produces phytase in its saliva (enviro pig) with better phytate phosphorus & micronutrient utilization & less excretion of phytic acid has been developed by Guelph University, Canada to address phytate induced MM.

Food chain approach

According to Slingerland et al. (2006) the food chain approach includes extended biofortification with appropriate post harvest technologies and special attention to dietary diversity. In order to increase the bioavailability of Fe and Zn from cereal-based foods various crop improvement steps has been taken. This interdisciplinary approach includes soil, water, and crop management to enhance uptake of micronutrients by plants. Research has also been focused on plant physiology & appropriate food processing methods to increase micronutrient content & reduce antinutritional factors. Understanding the location of the micronutrients and the mechanism of their interaction with antinutritional factors in plants can help to develop effective processing methods for improved bioaccessibility of micronutrients (Raes et al. 2014). Along with the above studies assessment to determine if improved foods lead to health impacts have also been initiated (Slingerland 2007). In Malawi a range of strategies plus promotion of the intake of other micronutrient-rich foods, including animal-source foods, resulted in improvements in both hemoglobin and lean body mass and a lower incidence of common infections among intervention compared with control children. (Hotz and Gibson 2007). A similar food chain approach that links agricultural production sectors with the urbanized consumers following a systems approach has been recommended for nutrient management in China (Sims et al. 2014)

Conclusions

Hunger & malnutrition are a mockery of the recognized fundamental human right to adequate food and nutrition. Scientists & policy makers of developing countries have been striving hard to stump MM. In spite of limitations of economy, infrastructure & resources long-term participatory intervention results in some of the Asian & African countries using food chain approaches have been encouraging. In micronutrient malnutrition management system such food chain approaches seem to be the most promising so far. However in order to provide 100% nutritional security developing countries should come up with their own food web approaches with well networked alternative food chains specific to the needs of the groups targeted. Such a food web should necessarily include food chains like comprehensive agriculture- nutrition management systems, education, extension & training programs along with proper implementation, monitoring & review of the same.

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