Review Article

To what extent can food-based approaches improve micronutrient status?

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The main dietary sources of micronutrients are animal source foods, fruits, vegetables and legumes. Animal source foods are the only source of some micronutrients and the main dietary source of others. Micronutrient status and child development are improved by animal source food interventions in populations that habitually consume low amounts. Of particular concern is the high global prevalence of vitamin B12 depletion, which is associated with low animal source food intake. Some fruits and vegetables can supply vitamin A requirements even with the lower amounts of fat typically consumed in many countries. However, plant source foods are unlikely to supply enough iron, zinc and vitamin B12, even if strategies such as consuming ascorbic-acid rich foods to increase iron absorption are adopted. Identification of mineral-rich varieties of cereals and legumes may improve the future situation. Complementary foods for infants and young children are unlikely to meet micronutrient requirements, especially for iron and zinc, unless they are fortified. Other strategies to improve micronutrient status, such as fortification and supplementation, have limitations and should not replace food-based strategies. Moreover, food-based strategies will improve dietary quality in general and are consistent with the global need to lower the risk of chronic disease and overweight.

Key Words: micronutrients, animal source foods, plant source foods, food-based strategies

INTRODUCTION

A variety of foods is needed to provide the many micronutrients required by humans. The main micronutrients of concern to public health are derived from different foods; vitamin A from dairy products, eggs, and fruits and vegetables rich in carotenoids; iron, zinc and vitamin B-12 from animal source foods (ASF); and folate from legumes, some fruits and vegetables, dairy products and eggs. ASF are the richest dietary source of micronutrients. Iodine is an exception as intake depends on the iodine content of the local soil and water, and deficiency should be addressed by strategies such as universal salt iodization.

Animal source foods

ASF are the only dietary source of vitamin B-12, vitamin D, and highly bioavailable iron and retinol. Per 100 kcal they also contain more riboflavin, vitamin E, and choline. In population groups consuming low amounts of ASF, there is a high prevalence of deficiency of all of these micronutrients. However, ASF vary greatly in micronutrient content. Eggs and liver (but not other meats) are good sources of retinol, and milk and eggs are lower in iron and zinc than meat, fish and poultry. Relatively few intervention trials have assessed the benefits of increasing ASF intake in population groups whose usual intake is low. In an efficacy trial in Kenya, schoolers were provided with supplemental meat or milk at one meal a day in school, for a total of about half of the days over a two-year period.[1] Protein and energy intakes were adequate in all groups. Compared to a control group supplemented with a similar amount of energy but low in micronutrients, many functional outcomes were improved by supplementation with the ASF, although these differed somewhat between the meat and milk intervention groups.[2]

Because vitamin B12 is only found in ASF (or fortified foods), the global prevalence of deficiency of this vitamin is high. For example, a review of Latin American studies in which plasma vitamin B12 was assessed revealed about a 40% prevalence of deficient (<150 pmol/L) and low (150-220 pmol/L) plasma B12 concentrations.[3] Likewise, about half of a group of adults in India had deficient or low concentrations, as did 70% of pregnant women in India and in Nepal. There is substantial evidence that the cause of these low plasma B12 levels is a low intake of ASF rather than malabsorption of the vitamin. Studies in industrialized countries have revealed that even lacto-ovo vegetarians are at risk of deficiency compared to omnivores. Of the Kenyan schoolers discussed above, 69% had a deficient or low plasma B12 concentration prior to the ASF intervention, and plasma levels were significantly correlated with usual intake of total ASF, meat, eggs or milk.[4]

Children in the lowest tertile of vitamin B12 intake were more than six times more likely to have low plasma B12

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than those in the upper tertile of intake. The meat or milk supplements significantly and substantially increased plasma B12, although recovery was slow, with status better after two years of supplementation than after one year.

Plant source foods

In spite of the realization that provitamin A carotenoids may be less efficiently converted to retinol than previously believed, several studies have now demonstrated that vitamin A requirements can be met from plant source foods. For example, 80 g of sweet potatoes or 75 g of Indian spinach, fed with oil twice daily for two months, significantly increased liver retinol stores of depleted Bangladeshi men.[5] The vitamin A equivalency of sweet potatoes was 13:1, and of the spinach, 9:1. Importantly, vitamin A equivalency was even higher in the men who were most depleted at baseline. Plant varieties, especially sweet potatoes, have been identified that are especially high in provitamin A carotenoids, and these improve vitamin A status even more effectively.[6] Although it is generally accepted that consuming plant source foods with fat improves the absorption of carotenoids, a new study in Filipino schoolers found no additional improvement in vitamin A status with 5 or 10 g of fat per meal compared to the usual dietary intake of 2.4 g/meal.[7] Feeding carrots, bok choy, squash and *kangkong* three times/day (4.2 mg provitamin A), five times/week for nine weeks doubled the total vitamin A body pool and reduced the prevalence of schoolers with low liver vitamin A from 35% to 7%. Thus, there is little doubt that it is feasible to meet vitamin A requirements from plant source foods, even using usual varieties and relatively low levels of dietary fat.

In contrast, it is very difficult to meet iron requirements with plant source foods. Because some plant source foods (including legumes and maize) are relatively high in non-heme iron, and absorption of this form of iron is enhanced by ascorbic acid, it is often recommended that vitamin C-rich foods or beverages be consumed with cereals or legumes to improve iron status. This is probably an unrealistic recommendation. In a test of the efficacy of this approach, *agua de limon*, a lime-based sweetened beverage in the traditional Mexican diet, was selected as a feasible source of ascorbic acid that might improve iron status in Mexico. When the beverage, supplying a total of 50 mg ascorbic acid/day, was consumed twice daily with high iron meals (tortillas and beans) it doubled the absorption of tracer-labeled iron from the meals. However, when the same feeding protocol was implemented for 8 mo under supervision, the iron status of iron-deficient women (who absorb iron most efficiently) failed to improve.[8] Ascorbic acid is however useful for improving iron absorption and status when feeding iron-fortified foods. Beans are a food with relatively high iron content, but only 2% is absorbed from the most common bean, *Phaseolus vulgaris*.[9] In contrast, iron absorption from soybeans was about 30% in iron deficient women, which is similar to that from meat because 90% of the iron in soybeans is in ferritin.[10] Iron bio-fortified rice may provide a strategy to improve population iron status in the future. In an efficacy trial in the Philippines, feeding this rice to women for 9 months improved iron status slightly but only in the most iron deficient women at baseline.[11] Varieties with even higher iron content need to be tested in larger-scale effectiveness trials.

Plant source foods that have relatively high zinc content include legumes, nuts and seeds, and whole grains. Legumes contain ≈1 mg/100g (cooked) or about 50% the concentration in meat. However the zinc status of legume-consuming populations is poor because only about 15% of zinc in legumes can be absorbed, due to their high phytate content.[12] Promisingly, absorption from a high zinc variety was 40%.[12] Zinc absorption from nuts and seeds, also high in zinc, has not been determined. A low-phytate maize hybrid increased zinc absorption in American men but when tested in Guatemalan school children absorption was 30% and did not differ between normal and low-phytate maize varieties.[13]

There is increased awareness of the need for adequate folate intake to lower the risk of neural tube defects. The recommended dietary folate intake is around 400 ug/day, which can be supplied quite readily from foods such as beans and chickpeas (260 ug/cup, cooked) and fruits and vegetables (30-260 ug/cup). However the content in cereals, milk and meat is relatively low, which may explain why low folate serum concentrations are reported more often in some industrialized countries such as Sweden and Chile (pre-fortification) than they are in many populations in poorer countries.[14]

The special problem of complementary feeding

It is difficult to meet the micronutrient requirements of infants and young children during the period of complementary feeding. Based on the average amount of breast milk consumed by partially breastfed infants beyond 6 months of age, it has been estimated that from 10% (for vitamin A) to 90% (for iron) of their micronutrient requirements need to be met from complementary foods. Analysis of food intake data from 6-11 month old infants in Bangladesh, Malawi and Guatemala revealed that their caregivers could provide them with foods adequate in protein, fat and energy, but micronutrients (especially B vitamins, iron and zinc) and calcium were unlikely to be provided in adequate amounts.[15] WHO recommends that one rounded teaspoon of cooked liver be provided daily as a complementary food, since this is one of the few food-based approaches that can provide enough iron and zinc. However, this advice is probably impractical and could cause vitamin A intakes to be excessive. Thus, strategies to meet the micronutrients required in complementary foods should include food fortification.

RECOMMENDATIONS

Food-based approaches to meet micronutrient intakes should always be the first priority. Greater dietary diversity has been associated with better growth[23] and micronutrient status in many studies. Fortification and supplementation strategies certainly have their place, but also have limitations. In fortification, there are limits to the amount of some micronutrients that can be added (iron, for example) due to their cost and effect on sensory properties of the food. In general, fortification policy is most effective when applied to a staple food consumed in sufficient amounts by the neediest groups in the population, so fortification of home-produced foods is difficult.

Compliance with supplementation programs is notoriously poor, and apart from some situations (such as supplementation of pregnant and lactating women, or children in school), these programs have been relatively ineffective. Supplementation also increases risk of adverse micronutrient interactions and adverse effects, for example the adverse effects of iron supplements on young children in areas with endemic malaria.[24]

Because food-based approaches to improve micronutrient status depend on improving the general quality of the diet by increasing fruit, vegetable and animal product intake, they can also provide the additional benefits of reducing the consumption of less nutritious carbohydrates and fats, and increasing the intake of the "other micronutrients" such as essential fatty acids and phytonutrients. This strategy is therefore consistent with the need to lower the global risk of chronic disease and overweight that is exacerbated by consumption of poor quality diets.

AUTHOR DISCLOSURES

Lindsay H Allen, no conflicts of interest.

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