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Editor's preface

On 27–28 August 1999, immediately prior to the Eighth Asian Congress of Nutrition in Seoul, Korea, a workshop was conducted on Dietary Approaches to Vitamin A Deficiency. It was organized by the United Nations University (UNU) and the International Union of Nutritional Sciences (IUNS), with the support of the Malaysian Palm Oil Promotion Council (MPOPC), the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), and the Micronutrient Initiative of Canada (MI). Participants included academic and government nutrition-related scientists and professionals from concerned international and bilateral agencies. All of the papers in this special issue of the *Food and Nutrition Bulletin* are based on presentations at this workshop, and most have been revised on the basis of the discussions.

Although the classical ocular manifestations of vitamin A deficiency, xerophthalmia and keratomalacia leading to blindness, or even the less serious Bitot's spots, are now rare, there is continuing concern for the health consequences of subclinical vitamin A deficiency. As shown in the 1980s, it significantly increases mortality from infectious diseases. UNICEF and WHO consider that on average a 23% reduction in mortality may result from improving the vitamin A status of young children with marginal vitamin A deficiency. The principal approach adopted by the international agencies has been the administration of a massive dose of synthetic vitamin A every six months.

Although this approach has been effective in many countries, it was originally intended as an interim measure to be replaced over time by improved diets. Moreover, there is increasing recognition that many of these vitamin A supplementation programmes do not maintain adequate coverage of those children most in need, and that they are rarely sustainable without outside financial support. Dietary approaches are needed to replace them, and this issue demonstrates that dietary approaches can be feasible and effective. Green and yellow vegetables and fruits with provitamin A activity are found in all developing countries.

Red palm oil, now produced in Malaysia, India, Venezuela, Costa Rica, and a number of other countries, is the richest natural source of biologically active precursors of vitamin A. Because refined palm oil is already widely consumed in Asia, Africa, and Latin America, carotene-rich red palm oil can also be produced and distributed where it is most needed. Papers presented in this workshop describe the production, nutritional value, and safety of red palm oil as well as experience with its use in developing countries for the prevention of vitamin A deficiency.

As dietary intakes of vitamin A and its precursors increase as a result of development and dietary intervention programmes, it should be possible to phase out dependence on support for massive-dose vitamin A supplementation. It is hoped that the proceedings of this workshop will stimulate and accelerate international and national support for dietary approaches to the prevention of vitamin A deficiency, and that they will call attention to the many green and yellow vegetables and fruits, as well as red palm oil, that are available for this purpose. Compared with other major micronutrient deficiencies in developing-country populations, vitamin A deficiency is the most amenable to prevention through improved diets.

Ed.

Dietary approaches to the control of vitamin A deficiency: An introduction and overview

Barbara A. Underwood

Abstract

As a public health problem, deficiency of vitamin A occurs when the habitual intake of bioavailable vitamin A is too little to meet physiological needs under prevailing conditions. Needs are increased during growth periods and when frequent infections cause inefficient utilization of the vitamin. Historical records and recent experience document that improved dietary intake, even when most vitamin A activity comes from provitamin A carotenoids, can correct the problem, especially when such diets contain adequate fat and the subjects are relieved of heavy worm infestation. An epidemiologic evaluation of the entire food chain, consisting of production, procurement, processing, and consumption, provides the framework for selecting suitable dietary approaches. These approaches include homestead food production, centrally or home-based fortified foods, and educational approaches promoting dietary diversification and modification of preparation practices to conserve the vitamin and render it more bioavailable. Even agricultural approaches that select and propagate germ plasma from varieties with increased micronutrient density can be utilized, including, in the future, genetic modifications to increase micronutrient density of vegetable and staple crops. Usually a mixture of intervention strategies will be most effective, particularly when social marketing accompanies efforts to increase consumer acceptance and compliance. Where the ecological and economic context prohibits dietary approaches, or where acute deficiency necessitates an immediate therapeutic response, distribution of vitamin A supplements is needed until suitable food-based approaches become feasible.

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Vitamin A deficiency and dietary control: Historical background

Vitamin A deficiency as a public health problem is caused by a dietary pattern providing too little bioavailable vitamin A to support physiological needs under the prevailing circumstances. Physiological needs vary with growth rates and may be conditioned by environmental factors that acutely or habitually cause inefficient utilization of vitamin A (e.g., infections). Through centuries of human existence, the problem probably evolved in parallel with changing lifestyles and food sources. Hunting and gathering wild animal meat, fish, nuts, fruits, and leaves (characteristic of early humans) provided highly bioavailable preformed vitamin A from animal foods and adequate fat and quality protein from meat, fish, and nuts to allow maximal utilization of less bioavailable provitamin carotenoids from wild fruits and leaves. However, as the human lifestyle became domesticated, plant foods increasingly replaced flesh foods, and cereals and grains—most of which were low in fat, lacked significant vitamin A, and provided protein of lesser quality—became the dietary staple, while domesticated vegetables provided provitamin A carotenoids.

Through the centuries before the common era and into the first millennium, ancient medical literature records cases of nyctalopia (night-blindness), for which ancient Egyptian and post-Hippocratic writings suggested a diet-based cure, consisting of animal liver extracts placed on the eye or ingested [1]. As the centuries passed, medical lore increasingly was replaced by systematic observations that noted similarities in symptoms between animals and humans consuming similar types of diets, and their remission in response to the addition of certain kinds of foods. Nutrition science, as applied to vitamin A, matured early in the twentieth century with the isolation, characterization, and synthesis of vitamin A and the elucidation of the ocular consequences of its deficiency [2]. It is notable that these early studies demonstrated that symptoms responded to food sources of preformed vitamin A, certain carotenoid-containing foods, and synthetic vitamin A, when it became available. Table 1 reproduces the list of foods that early investigators found associated with vitamin A potency [3].

These historical accounts provide the rational starting point for promoting dietary approaches based on diversification of dietary intake of vitamin A (including fortified foods), and they also support the use of synthetic supplements individually and among populations (where appropriate at the moment) for prevention and control of vitamin A deficiency worldwide.

What constitutes dietary (food-based) strategies?

To some, food-based strategies suggest only homestead gardens, which, they argue, are not a sustainable intervention for micronutrient control on a national scale. This view is too narrow and too top-down, donor-driven in focus. Food-based strategies should be viewed as encompassing the total food chain from production in gardens or fields, to procurement from local or centralized markets, to processing domestically in preparation of meals or commercially, to consumption within or outside the home.

Fortification fits well within this broader view of dietary approaches. Dietary strategies also should be viewed from a local or regional perspective, even when such perspectives are not applicable nationwide. Local opportunities can be tapped where these exist, not attempting to force the same strategy where the context is not receptive, e.g., where water or land shortage is prohibitive. The outcome indicator of successful dietary strategies for vitamin A should be access to a habitually consumed diet adequate to meet and maintain family needs, individually and collectively, for vitamin A and other essential nutrients.

TABLE 1. Association of vitamin A potency with yellow colour in food as identified by early investigations

Active (yellow)	Inactive, or low potency (white)
Butter	Casein
Egg yolk	Egg white
Cod liver oil	Lard
Yellow maize	White maize
Carrot	Parsnip
Sweet potato	Ordinary potato
Red palm oil	Palm kernel oil
Outer green leaves of cabbage	Inner white leaves of cabbage
	Onion
Tomato	Apple
Apricot	
Spinach	

Source: adapted from ref. 2.

Attributes of dietary strategies

Favourable attributes of dietary strategies include the following:

- » Multiple macro- and micronutrient deficiencies may be at least partially corrected through diversifying vitamin A sources in diets, e.g., green leafy vegetables contain iron, vitamin E, vitamin K, riboflavin, folate, and frequently vitamin C;
- » The natural balance of essential nutrients in foods minimizes the risk of adverse nutrient interactions and toxicity;
- » Household empowerment is enhanced through dietary strategies, e.g., informed household decisions facilitate self-reliant control over family well-being;
- » The underlying cause of vitamin A deficiency and of malnutrition in general, i.e., inadequate intake of nutritious foods relative to need, can be eased;
- » Leadership and management capacities are developed by dietary strategies that enable community participation in the identification, solving, and monitoring of problems, and as a consequence, overall community development is stimulated;
- » Flexibility in diversification, modification, and food-to-food enhancement of menus based on local resources is accommodated;
- » Functional components in food beyond those now recognized as beneficial for health are made available.

An often unappreciated strength is that dietary approaches frequently engage women and the poor in ways that foster culturally acceptable, sustainable solutions and in the process build self-worth, confidence, and reliance [4]. Empowerment of local communities cultivates holistic social and overall planning for community development, which, in turn, provides the underpinning for incremental national advancement [5].

Vulnerabilities of dietary approaches

There are vulnerabilities associated with dietary strategies that must be recognized. As skeptics assert, a unified national approach may be difficult because of variable conditions and resources across regions and within countries. Local adaptations are necessary and, therefore, require local planning where management skills may be lacking. Homestead food-production strategies are susceptible to seasonality, environmental disasters (e.g., persistent drought), and environmental contamination. Furthermore, among poor households, home food production is open to the economic draw of markets and to pressures to produce quantity from a few marketable crops rather than quality and diversity for home consumption to provide family nutritional and health gains.

Perceptions on dietary equivalency of carotenoid food sources

A Joint Food and Agriculture Organization/World Health Organization Expert Group report in 1967 [6] summarized the results of studies on the dietary equivalency of different sources of vitamin A activity. The variability was notable after feeding a variety of fruit and vegetable sources compared with pure β-carotene. None of the studies at that time evaluated dietary equivalencies from meals containing mixed sources of carotenoids. Consensus was reached, however, to set dietary vitamin A equivalency factors of 6:1 for β-carotene (i.e., 6 µg of β-carotene in the diet is equivalent to the nutritional activity of 1 µg of retinol), and 12:1 for other provitamin A carotenoids. A relative ranking of bioavailability based on a review of the published literature is provided in figure 1 [7]. No retinol equivalent (RE) factors are included, because the various methods currently used provide widely divergent results. Parker summarizes the strengths and weaknesses of these methods elsewhere in this issue [8]. Currently there is no consensus on the appropriate factor(s) to apply in evaluating the dietary potency of carotenoids in a mixed diet as consumed by healthy people. A panel of the Dietary Reference Intake committee of the US Food and Nutrition Board is currently examining the issue. Furthermore, little is known of how carotenoid dietary equivalency factors might be modified when applied to vitamin A–deficient persons who also are habitually exposed to enteric infections. Lack of consensus on bioavailability issues has hindered donor investments and promotion of dietary carotenoid-containing foods for control of vitamin A malnutrition [9].

Modifying intake by changing preparation procedures

The traditional practice of promoting increased consumption of natural foods by nutrition education presumes willingness to change eating behaviour. Experiences with sustained behavioural change resulting from nutrition education are limited. When successful, efforts usually involve innovative, but costly, social marketing and integration into community support structures. However, incremental improvements in vitamin A intake are possible by simple modification of household processing and cooking procedures that conserve vitamin A content and improve bioavailability [10]. For example, both stir-frying and prolonged boiling or open sun-drying are destructive to vitamin A activity from plant sources, whereas fine chopping, homogenization, light steaming, and solar or oven drying favour retention and bioavailability from diets [11, 12]. Gibson et al. discuss additional measures appropriate in an African setting [13].

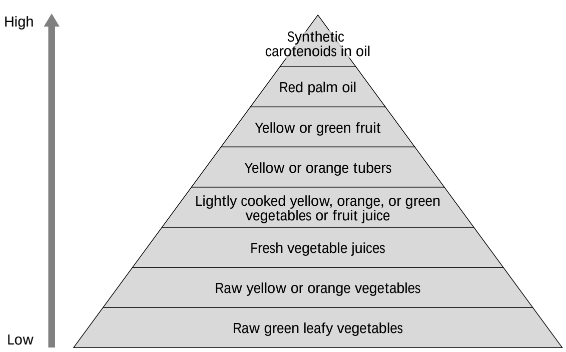

FIG. 1. Hierarchy of carotenoid bioavailability

Provitamin A food sources: Evidence of efficacy

Evidence for the effectiveness of provitamin A carotenoids is available from numerous epidemiological studies, case findings, and some controlled field trials. Published studies through the mid-1990s were reviewed by de Pee and West [14], who concluded that most reported studies lacked the rigorous designs necessary for conclusive evidence of efficacy. Indeed, there are very few "gold standard" randomized, controlled clinical trials, and conflicting evidence has come from the few that have been reported [15–19].

The totality and consistency of the evidence should be considered, especially when there are unanswered questions about the interpretation of some outcome indicators, such as pre- and post-intervention serum retinol values. Astute clinical observations should not be discarded, nor should community trials, even though some lack randomization. For example, Venkataswamy, a noted ophthalmologist in southern India, reported in 1976 that for severely malnourished South Indian children with xerophthalmia, diets that included green, leafy, freshly prepared vegetables from the rehabilitation centre's demonstration garden were as effective as synthetic vitamin A [20, 21]. Professor Devadas (a respected community-oriented Indian nutritionist) and colleagues reported three controlled community studies using balance techniques for comparing various local green leaves, leaf protein concentrate, and papaya to determine biological utilization among vitamin A–deficient children in southern India. When compared with β-carotene- or vitamin A–fed reference controls, all carotenoid food sources improved serum vitamin A above basal diet levels, although by lesser magnitude than the increase recorded after feeding pure β-carotene or retinol, with dark-green leafy vegetable sources being least effective [22–24]. Rao has reviewed other studies in India that demonstrate efficacy of plant foods and suggested explanations for the discrepancies [25].

Prominent among confounding factors influencing the efficacy of community feeding trials are dietary fat levels, intestinal parasite loads, and study populations whose initial serum levels of vitamin A are not deficient. The importance of fat was shown in the 1960s in African [26] and Indonesian [27] schoolchildren and in Guatemala [28]. Recently, Jalal et al. [15] and Takyi [17] confirmed in controlled trials among Indonesian and Ghanaian children, respectively, the importance of sufficient dietary fat and deworming for efficient carotenoid absorption. The serum levels of vitamin A were effectively improved in pre-school-age Ghanaian children who were dewormed and fed 400 g of cassava or kapok leaves (10 RE/child) daily under controlled conditions in an otherwise balanced diet containing adequate fat (20 g/child).

The apparent inconsistency between the epidemiological evidence and some controlled feeding trials may soon be resolved by improved and more precise studies using stable isotope tracer techniques. Tang et al. [29, 30] reported the use of stable isotopes to measure the response of total body stores to dietary interventions with plant carotenoids. Efficacy in maintaining stores from plant carotenoids was documented in Chinese children even when the calculated dietary equivalency ratio was 27 μg of β-carotene from vegetables to 1 μg of retinol, a fourfold lower factor than the 6:1 commonly used. To sort through these issues, these types of studies should be repeated when vegetables intrinsically labelled with stable isotopes are fed in meals. This will allow tracing the path from absorption and bioconversion from meals (dietary equivalency) to retention in body tissues in various states of vitamin A nutriture (nutritional equivalency). Although such studies are urgently needed, there is no reason to delay advocating dietary approaches, including plant provitamin carotenoids, for vitamin A deficiency control justified by the overall consistency of epidemiological evidence of effectiveness.

Increasing the vitamin A content of diets through agriculture

The epidemiology of vitamin A deficiency associates the problem with diets predominantly consisting of vitamin A–poor staples, such as cereals, grains, and tubers (e.g., rice, wheat, and cassava), and with little diversity; low and infrequent consumption of animal sources; and underconsumption of green and yellow vegetables and fruits. This picture generally describes economically and socially deprived households that are least able to adapt to seasonal food availability and are often bound by cultural biases in child-feeding practices.

Agriculturists recently have joined the efforts to confront vitamin A deficiency among the poor by traditional plant-breeding techniques applied to staple crops. Cultivars of staples that are naturally higher in provitamin carotenoids have been identified and propagated. These staples are unlikely to provide restorative levels of vitamin A to severe or moderately depleted persons but could make a significant contribution to maintaining adequate body stores once they have been restored through, perhaps, supplementation. For example, sweet potato cultivars have been identified that vary in their vitamin A equivalency from 13 to 912 RE per 100 g of fresh root. When promoted within a community development context as a women's crop initiative, the use of these cultivars improved the vitamin A status of Kenyan women and children [31]. Cassava cultivars have also been identified that contain enhanced levels of carotene in roots and leaves [32]. High-carotene varieties are being evaluated for their agronomic, organoleptic, and culinary properties and acceptability by farmers and consumers.

In addition to the calories and nutrients in the roots, the young leaves of both sweet potato and cassava are rich sources of β-carotene as well as other micronutrients. For example, it has been estimated that 5 g of fresh leaves (2 g of dry leaf flour) from genotypes of cassava identified with the highest concentration of carotenes in the leaves (105 mg/100 g vs 15 mg/100 g in genotypes with the lowest concentration) could provide between 3 and 4 mg of vitamin A equivalency, which is far above the recommended dietary allowance for a pre-school-aged child (about 400 μg/day) [33]. A comparable amount from the cassava root would require the ingestion of 200 g. Even wheat genotypes with β-carotene have been identified*. The poor in many countries grow and eat large quantities of cassava because it grows on marginal lands with minimal requirements, including requirements for water. Therefore, an increased nutritional contribution from varieties with increased micronutrient density could be significant for poor populations.

In addition, impressive breakthroughs are occurring with the use of transgenic techniques to create varieties of staple cereal grains tailored to optimize micronutrient content and bioavailability. For example, recently a genetically modified rice plant was announced that contains β-carotene in the grain in sufficient quantity to supply the daily requirement of vitamin A through consumption of just 300 g of cooked rice**. Furthermore, the transgenic rice has a twofold increased iron

* Graham RD, Rosser JM. Carotenoids in staple foods: their potential to improve human nutrition. Paper presented at the Workshop "Improving human nutrition through agriculture: the role of international agriculture research." International Rice Research Institute, Los Baños, Philippines, 5–7 October, 1999.

** Potrykus I, Lucca P, Ye X, Al-Babili S, Hurrel RF, Beyer P. Contributions to food security by genetic engineering with rice. Press release, 3 August 1999, St. Louis, Mo, USA.

content, contains a phytase gene to degrade phytic acid (a powerful iron-absorption inhibitor), and overexpresses the inherent iron absorption–enhancing, cysteine-containing rice proteins. Much laboratory work on safety, acceptability, and culinary properties remains before such promising breakthroughs will be available for general use. Nonetheless, in such genetically modified staples as well as natural cultivars selected for their greater nutrient density, the potential is greatly expanded for affordable, familiar diets that will sustain adequate micronutrient status [34].

Fortification

Voluntary fortification of dairy and a multitude of other products with vitamin A has been common practice in the United States and Europe for many years. In Guatemala mandatory universal fortification of sugar at a national level raised the vitamin A status of the population, which declined for a short period when the legislation was unenforced [35]. The non-mandatory, self-selection, sub-national fortification of margarine in the Philippines effectively improved serum vitamin A levels in a community trial, which has encouraged other private-sector partners to fortify other products [36]. A variety of centrally processed, commercially available fortified products, such as instant noodles, soya-based products, and fruit beverages, are now in urban markets in many Asian countries. The challenge is to develop consumer demand among vulnerable groups for fortified products and to make them available and affordable even to the poor, who usually are most in need and frequently reside in rural areas or urban slums where the problem is usually greatest.

Although experience is accumulating that a fortification approach is effective in some developing-country settings, there remain several countries, especially in Africa and South Asia, where effectiveness is yet to be demonstrated. In such countries, usually the food industry has not developed sufficiently to support centralized fortification, a food candidate with the necessary criteria for fortification is not available, or fortified foods are inaccessible or unaffordable by the populations at high risk for vitamin A deficiency. Furthermore, mandatory national programmes are subject to suspension based on political expediency, sometimes with disregard for the health consequences [35]. Nonetheless, fortification should be exploited as a dietary intervention where appropriate, because after initial capital investments, it is a relatively inexpensive intervention to address public health problems. An example of a successful dietary fortification strategy for control of a global public health problem is universal fortification of salt with iodine, which has greatly reduced goitre and controlled iodine-deficiency disorders.

Home-based fortification

Centrally processed fortified foods have dominated thinking for many legitimate reasons of quality control, efficiency of operations, and broad distribution of a marketable product. A more liberal definition of fortification, however, includes “food-to-food” fortification at the household level, which may be more practical where centralized fortification, as noted above, is not currently suitable. This approach assumes local availability of naturally rich food sources of vitamin A that are underutilized in the diets of high-risk groups. The approach encourages meal preparers to incorporate vitamin A–dense foods into traditional vitamin A–poor diets. Examples are presented elsewhere in this volume for *gac* in traditional rice dishes in Vietnam [37], liver chips as a snack in southern Thailand [38], and red palm oil incorporated into biscuits in child-feeding programmes in South Africa [39]. In northeast Brazil, the pulp from the palm fruit *buriti,* made into a sweet in communities and fed daily as a dietary supplement to children at high risk (12 g containing ~800 μg β-carotene or 134 μg retinol), resolved or attenuated clinical signs of vitamin A deficiency and normalized evidence of critically depleted body stores as measured by relative dose response [40]. In South India the β-carotene–rich blue-green alga *Spirulina*, prepared as a sweetened product suitable as a snack, improved the vitamin A status of pre-schoolers attending day-care centres [41]. Though not the traditional definition of fortification, the food-to-food concept introduced among hard-to-reach, high-risk communities has merit and can pave the way for the more traditional fortification approach when this becomes practical.

Nutrition education

Cynics often dismiss efforts to modify feeding and menu patterns through education, saying that children (and many adults) do not like to eat dark-green leafy vegetables and resist change. Perhaps, however, past failures in behavioural change are attributable to the educational process followed, which failed to create demand by changing recipients of information into clients anxious to receive information. Effective social marketing at a community level has been demonstrated to effectively imbed into community systems the necessary infrastructure to sustain behavioural change leading to improvement in vitamin A status, especially when women and the poor are active participants [4, 5, 31, 42].

Conclusions

An epidemiological perspective provides the framework for considering dietary approaches to control vitamin

A deficiency within the context in which the problem occurs, and it assists in identifying potentials for sustainable solutions. This perspective considers the environment in which foods are procured and prepared, the agents (nutrients) as consumed, and their physiological utilization. Such a holistic perception transcends the interface between environment and the host that utilizes nutrients in foods to fulfil crucial physiological functions.

There is substantial epidemiological evidence of the effectiveness of dietary approaches for the prevention and control of vitamin A deficiency when dietary strategies are well implemented. Dietary approaches provide a flexible armory of weapons, including diversity of possible foods, natural and value-added (fortified), and an array of modification in how they are prepared as well as the potential for long-term complementation to vitamin A supplementation programmes where these are needed to address an acute problem. Furthermore, the dietary armamentarium allows for variable means of procurement, e.g., through homestead gardens or community markets, and of preparation to maximize potential vitamin A activity as consumed. It is important to recognize, however, that dietary approaches may need to be complemented by additional approaches to maximize their effectiveness in the control of vitamin A deficiency. These other approaches may include control of infectious diseases, use of medicinal supplements, and improvement in economic and social conditions, particularly of women.

References

1. Wolf G. A historical note on the mode of administration of vitamin A for the cure of night blindness. Am J Clin Nutr 1978;31:290–2.
2. Underwood BA. From research to global reality: the micronutrient story. J Nutr 1998;128:145–51.
3. Moore T. Early evidence on the existence and nature of fat-soluble factor A. In: Moore T, ed. Vitamin A. New York: Elsevier, 1957:1–9.
4. Smitasiri S, Sa-gobwarchar K, Kongpunya P, Subsuwan C, Banjong O, Chitchumroonechokchai C, Rusami-Sopaporn W, Veeravong S, Dhanamitta S. Sustaining behavioural change to enhance micronutrient status through community- and women-based interventions in north-east Thailand: vitamin A. Food Nutr Bull 1999; 20:243–51.
5. Underwood BA, Smitasiri S. Micronutrient malnutrition: policies and programs for control and their implications. Annu Rev Nutr 1999;19:303–24.
6. Report of a Joint FAO/WHO Expert Group. Requirements of vitamin A, thiamine, riboflavin and niacin. WHO Tech Rep Ser No 362 (Appendix 3). Geneva: World Health Organization, 1967.
7. Boileau TWM, Moore AC, Erdman JW. Carotenoids and vitamin A. In: Papas AM, ed. Antioxidant status, diet, nutrition, and health. Washington, DC: CRC Press, 1999:133–58.
8. Parker RS. Methodological considerations in determining vitamin A and carotenoid bioactivity in humans. Food Nutr Bull 2000;21:124–9.
9. Solomons N. Plant sources of vitamin A and human nutriture: How much is still too little? Nutr Rev 1999; 57:350–3.
10. Wasantwisut E, Sungpuag P, Chavasit V, Chittchang U, Jittinandana S, Viriyapanich T. Identifying and recommending vitamin A rich foods in northeast Thailand. In: Wasantwisut E, Attig GA, eds. Empowering vitamin A foods. A food-based process for Asia and the Pacific Region. Salaya, Thailand: Mahidol University, Institute of Nutrition, and Bangkok, Thailand: Food and Agriculture Organization Regional Office for Asia and the Pacific, 1995:69–89.
11. Sungpuag P, Tangchitpianvit S, Chittchang U, Wasantwisut E. Retinol and β-carotene content of indigenous raw and home prepared foods in northeast Thailand. Food Chem 1999;64:163–7.
12. Chittchang U, Jittinandana S, Sungpuag P, Chavasit V, Wasantwisut E. Recommending vitamin A–rich foods in southern Thailand. Food Nutr Bull 1999;20:238–42.
13. Gibson RS, Hotz C, Temple L, Yeudall F, Mtitimuni B, Ferguson E. Dietary strategies to combat deficiencies of iron, zinc, and vitamin A in developing countries: development, implementation, monitoring, and evaluation. Food Nutr Bull 2000;21:219–31.
14. de Pee S, West CE. Dietary carotenoids and their role in combating vitamin A deficiency: a review of the literature. Eur J Clin Nutr 1996;50(Suppl 3):S38–53.
15. Jalal F, Nesheim MC, Agus Z, Sanjur D, Habicht JP. Serum retinol concentrations in children are affected by food sources of β-carotene, fat intake, and anthelmintic drug treatment. Am J Clin Nutr 1998;68:623–9.
16. de Pee S, West CE, Muhilal, Karyadi D, Hautvast JGAJ. Lack of improvement in vitamin A status with increased consumption of dark-green leafy vegetables. Lancet 1995;346:75–81.
17. Takyi EEK. Children's consumption of dark green, leafy vegetables with added fat enhances serum retinol. Am J Clin Nutr 1999;129:1549–54.
18. Bulux J, de Serrano JQ, Giuliano A, Perez R, Lopez CY, Rivera C, Solomons NW, Canfield LM. Plasma response of children to short-term chronic β-carotene supplementation. Am J Clin Nutr 1994;59:1369–75.
19. de Pee S, Bloem MW, Gorstein J, Sari M, Satoto, Yip R, Shrimpton R, Muhilal. Reappraisal of the role of vegetables in the vitamin A status of mothers in Central Java, Indonesia. Am J Clin Nutr 1998;68:1068–74.
20. Venkataswamy G, Krishnamurthy KA, Chandra P, Kabir SA, Pirie A. Lancet 1976;i:1120.
21. Venkataswamy G, Glover J, Cobby M, Pirie A. Xerophthalmia. World Rev Nutr Diet 1978;31:37–41.
22. Devadas RP, Murthy NK. Biological utilization of β-carotene from amaranth and leaf protein in preschool children. World Rev Nutr Diet 1978;31:159–61.

23. Devadas RP, Soroja S, Murthy NK. Availability of β-carotene from fresh and dried green leafy vegetables in preschool children. Indian J Nutr Diet 1978;15:335.
24. Devadas RP, Saroja S, Murthy NK. Availability of β-carotene from papaya fruit and amaranth in preschool children. Indian J Nutr Diet 1980;17:41–4.
25. Rao BSN. Bioavailability of β-carotene from plant foods. Bull Nutr Found India 1996;17:1–5.
26. Roels OA, Trout M, Dujacquier R. Carotene balances in boys in Ruanda where vitamin A deficiency is prevalent. J Nutr 1958;65:115–27.
27. Roels OA, Djaeni S, Trout ME, Lauw TG, Heath A, Poey SH, Tarwotjo MS, Sushadi B. The effect of protein and fat supplements on vitamin A–deficient Indonesian children. Am J Clin Nutr 1963;12:380–7.
28. Arroyave G, Flores M, Béhar M. The effect of a controlled increment in dietary nutrient intake on blood and urine biochemistry in children. Am J Clin Nutr 1964; 15:331–40.
29. Tang G, Gu X, Hu S, Xu Q, Qin J, Dolnikowski GG, Fjeld CR, Gao X, Russell RM, Yin S. Green and yellow vegetables can maintain body stores of vitamin A in Chinese children. Am J Clin Nutr 1999;70:1069–76.
30. Tang G, Qin J, Hu S, Hao L, Xu Q, Gu X-F, Fjeld CR, Gao X, Yin S-A, Russell RM. Protection of vitamin A status in Chinese children by a dietary intervention with vegetables. Food Nutr Bull 2000;21:161–4.
31. Hagenimana V, Oyunga MA, Los J, Njoroge SM, Gichuki ST, Kabira J. The effects of women farmers' adoption of orange-fleshed sweet potatoes: raising vitamin A intake in Kenya. Washington, DC: International Center for Research on Women, Research Report Series 3, June 1999.
32. Inglesias C, Mayer J, Chavez L, Cale F. Genetic potential and stability of carotene content in cassava roots. Euphytica 1997;94:367–73.
33. Update No. 2. CGIAR (Consultative Group on International Agricultural Research) Micronutrients Project. Washington, DC: International Food Policy Research Institute, October 1997.
34. Bouis HE. Economics of enhanced micronutrient density in food staples. Field Crops Res 1999;60:165–73.
35. Solomons NW, Bulux J. Vitamin A fortification survives a scare in Guatemala. Sight and Life Newsletter, February 1998.
36. Solon FS, Sanchez-Fermin LE, Wambangco LS. Strengths and weaknesses of the food fortification programme for the elimination of vitamin A deficiency in the Philippines. Food Nutr Bull 2000;21:239–45.
37. Vuong LT. Underutilized β-carotene–rich crops of Vietnam. Food Nutr Bull 2000;21:173–81.
38. Wasantwisut E, Chittchang U, Sinawat S. Moving a health system from a medical towards a dietary approach in Thailand. Food Nutr Bull 2000;21:157–60.
39. van Stuijvenberg ME, Benadé AJS. South African experience with the use of red palm oil to improve the vitamin A status of primary schoolchildren. Food Nutr Bull 2000;21:212–4.
40. Mariath JGR, Lima MCC, Santos LMP. Vitamin A activity of buriti (*Mauritia vinifera* Mart) and its effectiveness in the treatment and prevention of xerophthalmia. Am J Clin Nutr 1989;49:849–53.
41. Annapuma VV, Deosthale YA, Bamji M. Spirulina as a source of vitamin A. Plant Foods for Human Nutrition 1991;41(2):125–34.
42. Parlato M, Gottert P, Mamadoultaibou A, Ferdows B. Niger: promoting consumption and production of vitamin A–rich foods. In: Palato M, Seidel R, eds. Large-scale applications of nutrition behavior change approaches: lessons from West Africa. Technical report. Arlington, Va, USA: BASICS (Basic Support for Institutionalizing Child Survival), 1998:25–33.

Methodological considerations in determining vitamin A and carotenoid bioactivity in humans

Robert S. Parker

Abstract

At present there is little information regarding the quantitative vitamin A value of specific foods or meal patterns. Such information would aid in a more precise determination of the suitability of certain foods or diets to meet minimum and optimal nutritional needs for vitamin A. This knowledge deficit stems largely from the lack of well-developed models to assess the bioavailability of carotenoids, particularly provitamin A carotenoids, from foods. Literature values of carotenoid bioavailability (percent of ingested carotene absorbed) range from 1% to 99%, and variability is often high both within and between treatments. Current models generally fall into two categories: those employing outcomes that reflect efficacy, i.e., that rely on changes in one or more indicators of vitamin A status; and those which provide a more direct estimate of absorption and/or conversion efficiency of single doses of provitamin A carotenoids. The latter include oral–faecal balance models and post-prandial chylomicron retinyl ester response models. Absolute bioavailability, i.e., the mass of newly absorbed vitamin A derived from a given mass of provitamin A carotenoid consumed, is inherently more problematic to assess than relative bioavailability, in which two or more treatments are compared. One missing and key piece of information is the extent of post-absorptive conversion of provitamin A carotenoids to vitamin A in humans. Without such information, the contribution of absorbed β-carotene or plasma β-carotene to vitamin A status will remain clouded. Recent estimates of the vitamin A value of plant foods suggest that in some cases plant-based diets may be insufficient to improve vitamin A status, yet in some circumstances this prediction has proved inaccurate. This paper will contrast several of the more recent methods of assessing the bioavailability of food-borne provitamin A carotenoids to illustrate the potentially complementary nature of the two categories of bioavailability model.

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Introduction

The vitamin A value of provitamin A carotenoids has been the subject of investigation for over 50 years. However, there remains considerable uncertainty regarding the quantitative aspects of the contribution of such carotenoids to vitamin A nutriture. This paper focuses on aspects of the more commonly applied models that have been used to determine the vitamin A value of provitamin A carotenoids contained in foods or supplements. In so doing, we seek to identify potential pitfalls and sources of confusion surrounding the investigation of "bioavailability" of provitamin A carotenoids. Not reviewed here are applications dealing with the bioavailability of carotenoids *per se*, exclusive of their vitamin A contribution. A review of that topic has recently appeared [1].

An appreciation of the relative merits of various models of assessment of the vitamin A value of provitamin A carotenoid-containing products requires an understanding of the processes of absorption, metabolism, distribution, and utilization of carotenoids and retinoids. Such a discussion is beyond the scope of this paper, and several reviews of these subjects are available [2–5]. However, certain phenomena are directly relevant to the design and interpretation of models of provitamin A carotenoid bioavailability (fig. 1), and will be briefly summarized. Since β-carotene is the predominant provitamin A carotenoid worldwide, and the best characterized of the provitamin A carotenoids, the term "β-carotene" will generally be used in place of "provitamin A carotenoid."

β-Carotene must first be released from its ingested matrix by digestive processes before it can be taken up into the intestinal mucosa by diffusion. Digestion and mucosal uptake are facilitated by biliary constituents (bile acids and phospholipids), secreted enzymes, and meal-derived lipids. Within the mucosa, some β-carotene is metabolized to retinyl esters, and both retinyl esters and β-carotene escaping conversion are secreted into lymph exclusively associated with triglyceride-rich chylomicrons. An important point is that chylomicron secretion by

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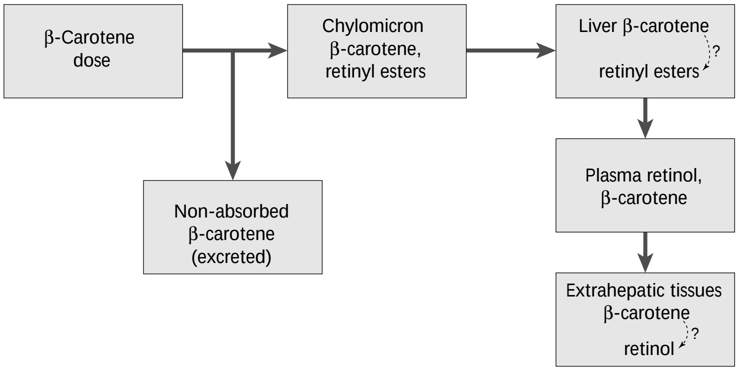

FIG. 1. Process associated with the absorption, metabolism, and distribution of β-carotene and retinol in humans relevant to the assessment of carotenoid bioavailability. The extent of post-absorptive conversion of β-carotene to retinol (or retinyl esters), either in liver or extrahepatic tissues, is currently unknown

the intestine is dependent on meal triglyceride content; in the case of very low meal triglyceride content, β-carotene may be taken up into the mucosa but not secreted into the lymph. Delayed secretion stimulated by a subsequent meal is known to occur. Lymph chylomicrons are secreted into the bloodstream, where they are rapidly delipidated by lipoprotein lipase and are rapidly taken up by the liver, with a half-life of several minutes. Since both retinyl esters and β-carotene are components of the core of the chylomicron particle, they remain with the chylomicron remnants until cleared by the liver. The liver will secrete some newly absorbed β-carotene in very low density lipoprotein, whereas retinyl esters are not secreted. Instead, some proportion of new retinyl ester will be hydrolysed and secreted bound to retinol-binding protein. The extent of post-absorptive conversion of β-carotene to retinol in humans is currently not known.

The concentration of plasma retinol is under homeostatic control and therefore will not increase in response to newly absorbed vitamin A, except in the case of vitamin A deficiency where liver stores are low. On the other hand, vitamin A status has no effect on the uptake of β-carotene by the intestinal mucosa or on the secretion of β-carotene or retinyl esters in chylomicrons. Thus, ingestion of β-carotene results in absorption of new retinyl esters, assimilation of this new vitamin A into the body pool, and potentially a change in one or more measures of vitamin A status, such as plasma retinol concentration. The latter may subsequently result in a functional outcome manifested by measurable clinical end points, such as ocular function, morbidity, or mortality. Most models used to assess the “bioavailability” of provitamin A carotenoids involve measures of newly acquired vitamin A or alterations in vitamin A status (fig. 2).

The term “bioavailability” will be used here to mean the ability of a provitamin A carotenoid–containing product to contribute new vitamin A to the body pool of vitamin A. Ultimately, the term is defined by how a particular investigator chooses to measure it, and therefore the term by itself has taken on many meanings in the context of provitamin A carotenoids. The commonly applied models largely fall into two groups, depending on how bioavailability is determined: those which seek to measure newly acquired vitamin A resulting from recent intake of carotenoids, and those which determine the extent to which a treatment can improve some measure of vitamin A status. These two approaches are inherently distinct and should not be compared from the standpoint of merit or validity. Rather, they yield different and complementary information, and each must be interpreted within the constraints of both model and experimental design.

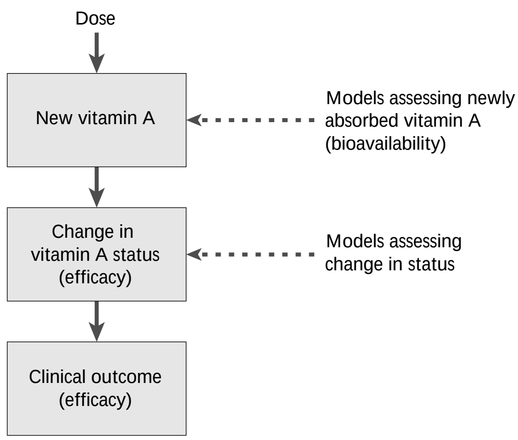

FIG. 2. Relationship between (pro) vitamin A intake, vitamin A assimilation, change in vitamin A status, and clinical outcomes related to status. Current models assess either the extent of assimilation of ingested vitamin A or a change in vitamin A status

Before discussing these two groups of models, it is useful to distinguish between *absolute* and *relative* bioavailability. Absolute bioavailability is a quantitative term referring to the actual amount (mass) of vitamin A derived from a given treatment, and is usually expressed in terms of amount assimilated per unit mass consumed. In the present context, it can be represented as the mass of retinyl ester derived from a given mass of provitamin A carotenoid (β-carotene) consumed. In contrast, relative bioavailability represents a comparison of two or more treatments, in which one treatment is designated as the control or reference treatment. This approach is most often taken when it is not possible or feasible to obtain the absolute bioavailabilities of the individual treatments. Thus, although the actual amounts of vitamin A obtained from the treatments may be unknown, conclusions regarding the "relative value" can be made, provided that the reference treatment is suitably designed and the comparisons are valid. Since the term "bioavailability" is often taken to mean absolute bioavailability, studies involving relative assessments should be clearly labelled as such.

Models to measure newly acquired vitamin A

Very few models have been developed that quantitate the amount of new vitamin A assimilated after ingestion of provitamin A carotenoids. Some models seek to address this indirectly by assessing the absorption efficiency of the substrate, β-carotene. These include the oral–faecal balance model and its more recent relative, the intestinal washout model. Both measure absorption efficiency by comparing faecal output with oral intake of single doses. Neither model yields information on the amount of vitamin A that may have been derived from the dose. However, the amount of retinyl ester assimilated is a function of both mucosal carotene uptake and mucosal conversion of β-carotene to vitamin A, and such models do address the first of these phenomena.

One model applied with increasing frequency since 1995 [6] is the so-called chylomicron response model, in which post-prandial changes in the concentration of retinyl esters in the plasma triglyceride-rich lipoprotein (TRL) fraction are used to draw inferences as to the mass of vitamin A derived from a test meal (dose). The value of this approach stems from the facts that chylomicrons and their remnants, contained in the TRL fraction, are the exclusive means by which newly absorbed β-carotene and derived retinyl esters are transported from the intestine to the liver; and that retinyl esters are not resecreted by the liver or associated with other lipoproteins. In fact, retinyl palmitate has been used for many years as a valuable *in vivo* marker for studying chylomicron kinetics in humans [7].

In the post-prandial chylomicron response (PPC) model, data from multiple blood samples drawn over periods ranging from 8 to 16 hours after a test meal are used to construct concentration versus time plots, from which area-under-the-curve (AUC) values are computed. Such values are assumed to be proportional to the amount of retinyl ester produced by the intestinal mucosa. There are currently two variants of this model, referred to here as PPC without extrinsic reference and PPC with extrinsic reference. In the former, the retinyl ester AUC is most often used to assess the *relative* vitamin A yield, i.e., in comparing two or more treatments with respect to their resulting TRL-retinyl ester response (AUC). In one instance, published chylomicron kinetic constants were used to calculate the absolute amounts of retinyl ester and β–carotene absorbed subsequent to a β-carotene dose [6]. This exercise resulted in the estimate that approximately 11% of a dose of β-carotene, in gelatin beadlet form, was absorbed, as the sum of β-carotene *per se* plus derived retinyl ester.

A potential drawback of this model is the lack of a means of controlling for intra- or inter-individual variation in chylomicron kinetics (e.g., rate of liver clearance of chylomicron remnants), or for variation in particle recovery during the ultracentrifugation process required to obtain the TRL fraction. The concentration of retinyl ester in the TRL fraction observed at any one time point is determined not only by the rate of retinyl ester actually synthesized and secreted by the intestine into the bloodstream, but also by the rate at which chylomicron remnants containing these retinyl esters are cleared by the liver. Since the rate of clearance is variable, variation in the instantaneous TRL retinyl ester (or β-carotene) concentration, and therefore the integrated retinyl ester AUC, may *not* reflect variation in the mass of retinyl ester actually secreted by the intestine. Additionally, ultracentrifugation may capture only a portion of the total chylomicron population [7], and therefore only a portion of the newly absorbed retinyl ester, depending on the conditions used. In the absence of a physiological "internal standard," it must be assumed that both chylomicron kinetics and ultracentrifugation recovery are either constant or equally variable across treatments or individuals.

Our laboratory has recently developed a variant of the chylomicron response model, "PPC with extrinsic reference," in an attempt both to counter these drawbacks and to provide an internal comparison between food sources of β-carotene and preformed vitamin A. A preliminary description of this approach has appeared [1]. This approach involves co-feeding a test meal containing the commodity of interest with a small amount (2 mg) of deuterium-labelled retinyl ester (d_4-retinyl acetate), the latter dissolved in oil solution (ideal physical form). This stable isotope-labelled retinyl ester constitutes an internal reference against which to compare the retinyl ester response resulting from the food (carotenoid) under study, while at the same time controlling for *in vivo* chylomicron clearance kinetics and for recovery during ultracentrifugation. The use of labelled retinyl ester as the reference provides an internal and direct comparison with the conventional means of treating vitamin A deficiency, i.e., retinyl ester in oil solution. If one applies an assumed absorption efficiency (e.g., 80%) for the extrinsic retinyl acetate reference, the mass of retinyl ester or β-carotene derived from the food can be directly calculated. We have used this approach to estimate that only 2.5% to 4% of carrot carotenes are assimilated as the sum of carotenes and retinyl esters after a meal containing 19 mg of β-carotene in cooked carrot. The mean β-carotene:retinol mass equivalency ratios calculated from data obtained with this method have ranged from 21:1 to 42:1, in contrast to the conventionally applied 6:1 mass equivalency, depending on commodity and dose, with considerable inter-individual variation in some circumstances.

One key to accurate measurement of the vitamin A derived from a recent meal is the ability to discriminate newly absorbed vitamin A from that pre-existing in the body, especially if measurements are made using unfractionated plasma. An approach that may be of value in this regard is the use of foods intrinsically labelled with deuterium or carbon-13. Despite the substantial technical difficulties associated with the production of such foods and, in some cases, the analytical procedures involved, such efforts are under way and should bear fruit in the near future.

Models that assess change in vitamin A status

The second general approach used to assess the vitamin A bioactivity of provitamin A carotenoids employs models based on change in vitamin A status. In most instances, treatments have been compared with respect to their ability to improve one or more measures of vitamin A status in populations previously determined to be at least marginally deficient in vitamin A. This is a useful approach, since a large proportion of the rationale for determining the vitamin A value of foods is to apply such data to the alleviation of vitamin A deficiency. Whereas the models discussed above provide more direct and quantitative data on the relative or absolute vitamin A value of specific foods or meals, newly acquired vitamin A may or may not result in a change (improvement) in vitamin A status.

Thus, from an applied standpoint, studies using changes in vitamin A status as end points are necessary. But it is important to recognize that such models reflect the "efficacy" (or most commonly, relative efficacy) of treatments, and that efficacy and bioavailability are not synonymous terms. A given treatment (commodity) may be bioavailable in terms of providing vitamin A yet be of low efficacy because of the failure of the chosen end point to respond in a given circumstance. Efficacy is impacted by factors that include, but are not limited to, the bioavailability of provitamin A carotenoids in the treatment. There are numerous host-related factors and conditions that may impact an efficacy end point independently of the actual vitamin A contribution of the treatment. These include vitamin A status, increased rate of host utilization of vitamin A (pregnancy and possibly infection), increased rate of elimination of vitamin A (lactation and infection), and compliance with the treatment. Only after ruling out significant contributions from these factors can conclusions regarding the vitamin contribution of the treatments *per se* be made.

There are numerous indicators of vitamin A status, and each can exhibit a different sensitivity (dose–response) to a change in vitamin A acquisition [8]. End points that have been used in assessing the vitamin A value of food- or supplement-based interventions in human populations include change in serum retinol over baseline after prolonged treatment, the relative dose response, modified relative dose response (dehydroretinol:retinol ratio), serum retinol-binding protein, breastmilk vitamin A, liver biopsy vitamin A, and total body vitamin A pool, as estimated by isotope dilution of labelled retinol [9]. All except the last are severely impacted by the vitamin A status of the host, such that if vitamin A status is insufficiently deficient, the indicator may not respond at all, potentially leading to erroneous conclusions regarding the actual vitamin A contribution of the treatment. The change in serum retinol approach has been used to estimate a β-carotene:retinol mass equivalency of 12:1 for fruits and 26:1 for green leafy vegetables and carrots, based on a comparison with preformed vitamin A–rich foods [10].

The isotope dilution method is considered a measure of status rather than of newly acquired vitamin A, since the end point can be influenced by the host factors listed above. However, given constant conditions, a change in body stores subsequent to intervention may reflect the vitamin A value of the treatment, and such changes may be used to infer the vitamin A value of the treatment. Such an approach has been applied by Tang et al. [11] to estimate a β-carotene:retinol mass equivalence of 27:1 for a mixed vegetable diet. In addition, unlike other status end points, the isotope dilution approach will be less affected by the vitamin A status of the host, and can theoretically be applied in well-nourished subjects. Unfortunately, studies of the vitamin A value of plant foods employing status end points have only rarely incorporated a control treatment with preformed vitamin A. The current intervention of choice in circumstances of vitamin A deficiency is infrequent high doses of retinyl palmitate. Future studies of the vitamin A value of foodstuffs, particularly in the case of serum retinol response but regardless of the model employed, would be well served to incorporate such a preformed vitamin A treatment comparison.

Contrasts and congruencies of models of assessment of the vitamin A value of provitamin A carotenoids

Each bioavailability model has its own inherent strengths and limitations. Some of these have been discussed above, but others bear mentioning. PPC-based models are potentially valuable for more quantitative assessment of the vitamin A value of specific foods, since they can be conducted in a closely controlled fashion. Such data may obviate the necessity of applying a single β-carotene:vitamin A mass equivalency value (currently 6 μg β-carotene:1 μg retinol) to all foods consumed under all circumstances, as is the case at present. These models can also directly investigate the effects of meal composition (fat and fibre content), cooking and processing practices, and interactions between specific carotenoids [12], in order to better guide food-based recommendations.

However, although PPC-based models can yield more direct and definitive data on the vitamin A value of specific foods or supplement formulations than can models reliant on vitamin A status end points, they can be applied only under certain circumstances. First, at present the blood requirements preclude their application in infants and young children, and perhaps in some adult populations. Second, the PPC-based models measure only the vitamin A that results from intestinal conversion of provitamin A carotenoids to retinyl esters. Whereas the extent of post-absorptive conversion of carotenes to vitamin A appears low in experimental animals [13], it is virtually unknown in humans, and to the extent that it does occur it will result in underestimation of food vitamin A values obtained with this approach. Methodological approaches to address this aspect of carotenoid metabolism are now becoming available.

As discussed above, the results of studies of the vitamin A yield of single meals in metabolic studies and those of comparative studies in vitamin A–deficient populations using vitamin A status end points should be considered as complementary, rather than as substitutes. Predictions of efficacy in population studies based on results from single-dose human metabolic studies may not always be realized because of the additional physiological and environmental variables impinging upon the former. However, recent findings both from population intervention studies with vitamin A status end points (serum retinol response and total body vitamin A stores by isotope dilution) and from PPC-based metabolic studies [1, 6] suggest that the commonly applied β-carotene:retinol mass equivalency of 6:1 overestimates the metabolic vitamin A value of β-carotene from at least some plant foods. The 6:1 mass equivalency ratio assumes an intestinal uptake efficiency of 33%, and a conversion efficiency of 50%. Recent data from PPC models suggest that the conversion efficiency assumption of 50% is appropriate, at least for well-nourished persons. However, the intestinal uptake efficiency appears substantially overestimated for most of the β-carotene sources studied to date, possibly by as much as tenfold for some foods. This suggests that the limiting factor in the vitamin A value of foods or supplements is the efficiency of digestion and release of β-carotene from its ingested matrix, and its subsequent incorporation into mixed lipid micelles and mucosal uptake. Future studies of the factors significantly impacting food vitamin A value may wish to focus on these phenomena, including those controllable variables which affect them. Such variables include particle size (surface area, particularly for indigestible food matrices such as carrot), method of preparation (heat treatment), and meal fat or fibre content. The distinction between digestible and indigestible matrix may be important, since in the case of the former, as the β-carotene dose increases so will the dose of fibre, which may counterbalance the increased intake of provitamin A carotenoid.

References

1. Parker RS, Swanson JE, You C-S, Edwards AJ, Huang T. Bioavailability of carotenoids in human subjects. Proc Nutr Soc 1999;58:155–62.
2. Parker RS. Absorption, metabolism and transport of carotenoids. FASEB J 1996;10:542–51.
3. Blomhoff R, Green MH, Green JB, Berg T, Norum KR. Vitamin A metabolism: new perspectives on absorption, transport and storage. Physiol Rev 1991;71:951–90.
4. Ong DE. Cellular transport and metabolism of vitamin A: roles of the cellular retinoid-binding proteins. Nutr Rev 1994;52:S24–31.
5. Olson JA. Recommended dietary intakes (RDI) of vitamin A in humans. Am J Clin Nutr 1987;45:704–16.
6. van Vliet T, Schreurs WHP, van den Berg H. Intestinal β-carotene absorption and cleavage in men: response of β-carotene and retinyl esters in the triglyceride-rich lipoprotein fraction after a single oral dose of β-carotene. Am J Clin Nutr 1995;62:110–6.
7. Le N-A, Gallagher PR, Cortner JA. Kinetics of retinyl esters during postprandial lipemia in man: a compartmental model. Metabolism 1997;46:584–94.
8. de Pee S, Yuniar Y, West CE, Muhilal. Evaluation of biochemical indicators of vitamin A status in breast-feeding and non-breast-feeding Indonesian women. Am J Clin Nutr 1997;66:160–7.

9. Haskell MJ, Handelman GJ, Peerson JM, Jones AD, Rabbi MA, Awal MA, Wahed MA, Dilip M, Brown KH. Assessment of vitamin A status by the deuterated-retinol-dilution technique and comparison with hepatic vitamin A concentration in Bangladeshi surgical patients. Am J Clin Nutr 1997;66:67–74.
10. de Pee S, West CE, Permaesih D, Martuti S, Muhilal, Hautvaust JGAG. Orange fruit is more effective than are dark-green, leafy vegetables in increasing serum concentrations of retinol and β-carotene in schoolchildren in Indonesia. Am J Clin Nutr 1998; 68:1958–67.
11. Tang G, Qin J, Hu S, Hao L, Xu Q, Gu X-F, Fjeld CR, Gao X, Yin S-A, Russell R. Protection of vitamin A status in Chinese children by a dietary intervention with vegetables. Food Nutr Bull 2000;21:161–4.
12. van den Berg H, van Vliet T. Effect of simultaneous, single oral doses of β-carotene with lutein or lycopene on the β-carotene and retinyl ester responses in the triacylglycerol-rich lipoprotein fraction of men. Am J Clin Nutr 1998; 68:82–9.
13. Thatcher AJ, Lee CM, Erdman JW Jr. Tissue stores of β-carotene are not conserved for later use as a source of vitamin A during compromised vitamin A status in Mongolian gerbils (*Meriones unguiculatus*). J Nutr 1997;128:1179–85.

Finding food sources of vitamin A and provitamin A

Harriet V. Kuhnlein

Abstract

Food-based programmes have the potential to effect long-term and sustainable solutions to the problem of vitamin A deficiency. Dietary sources of vitamin A and provitamin A, including natural and fortified food, are multiple and include a variety of plants, animals, and their fats and oils. These may be available to the community or the individual routinely or only seasonally, and their effectiveness in vitamin A nutrition is dependent on a host of issues affecting bioavailability and other health and nutrition circumstances. Procedures are now attainable to define the holistic framework of local availability and cultural acceptability of vitamin A–containing food, and the perceptions and other factors that influence its harvest, preparation, preservation, and consumption. This kind of information is essential to bring behavioural change in dietary patterns to improve vitamin A status. A wealth of information on vitamin A– and provitamin A–rich food species exists within traditional food systems of indigenous peoples. Research to scientifically define these foods, their vitamin A contents, and constraints on availability and cultural acceptability will benefit food-based strategies to prevent and alleviate vitamin A deficiency.

Background

Food-based programmes have the potential to prevent and alleviate vitamin A deficiency by providing long-term and sustainable solutions. In this respect, food is defined as whole, refined, processed, fortified, or a combination of these, and the provisioning of food to vulnerable groups depends on a variety of intersectoral influences [1]. There are many kinds of food providing vitamin A or provitamin A, with sources being plant or animal species, or the fats or oils made from them. The levels of nutrients in food depend on natural sources of variation in the species (soil, genetic diversity, seasonality, stage of maturation, etc.), the effects of processing, and possible fortification with vitamin A [2].

The effectiveness of dietary vitamin A in preventing and alleviating vitamin A deficiency is also influenced by factors of bioavailability of retinol or carotenoids. In turn, bioavailability from specific foods may be influenced by a host of nutritive and non-nutritive substances in those foods that affect absorption and metabolism. In addition, total dietary protein, fat, vitamin E, and zinc are nutrients known to affect vitamin A status [3]. Other physiological and health factors that influence the vitamin A status of the individual include the need for normal digestion and absorption processes, normal protein and fat status, hormone status, stage of growth, and absence of infection [4].

Although the importance of these factors cannot be overestimated, the purpose of this article is to describe a process by which unique sources of vitamin A and provitamin A can be identified within the food systems of vulnerable groups. This process is also useful for identifying likely food carriers for vitamin A fortification programmes.

How can vitamin A needs be met by food?

Understanding how vitamin A needs can be met by food requires knowledge of three basic dietary evaluations:

» What food is consumed: what species, and how is it prepared?—to ultimately arrive at the nutrient composition of the food as consumed;
» How much food may be consumed?—this may be influenced by age and sex;
» How often may the food be consumed?

Each of these dietary evaluation principles (what food, how much, and how often) can be profoundly influenced by the factors of environmental availability and cultural acceptability of the food. Good sources

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of vitamin A and provitamin A for meeting the needs of populations at risk must be both available and acceptable at the local, household, and personal levels.

The environmental availability of local food species rich in vitamin A obviously depends on climate and seasonality. In addition, the quality of the environment (freedom from pollutants and other hazards), the local ecology (especially if wildlife resources are considered), and the availability of agricultural land may all influence the presence of food species in local markets, communities, and households. Technological factors that may influence food availability include harvesting techniques (are they accessible?), preservation of food (is it easily accomplished?), distribution to those vulnerable, and technologies required for home food preparation (is the equipment accessible?). If any one of these factors falls short, the sources of vitamin A and provitamin A may not be available to those in need.

The acceptability of food sources of vitamin A and provitamin A is reflected by cultural preferences, affordability, and possibly the effectiveness of education and the media for the vulnerable population. Cultural preference is a large topic to consider, requiring understanding of relevant beliefs and health perceptions about vitamin A needs and food to meet them. It also includes the local priorities for food flavours, colours, textures, and aromas, and the dietary structures (types and numbers of meals consumed per day) into which food is incorporated. Cultural preferences also may dictate the kind of food consumed in social events or for personal circumstances (for example, during pregnancy, infancy, or illness).

Successful food sources of vitamin A must be "acceptably affordable." That is to say, those in need must be able to access the food, should they be convinced they want it. It needs to be available for an acceptable amount of personal time and energy expenditure, or for an affordable cost within the household or personal income structure. Finally, food sources of vitamin A or provitamin A that are new in local knowledge must be introduced with education or media techniques in ways that make the foods culturally acceptable to the community and the individual [5, 6].

A protocol for the community assessment of natural food sources of vitamin A and provitamin A

A project created by the Committee on Nutrition and Anthropology of the International Union of Nutritional Sciences and sponsored by the International Development Research Centre of Canada, with publication support from the International Nutrition Foundation for Developing Countries, developed a variety of ethnographic techniques to determine local food sources of vitamin A and provitamin A that are available and acceptable to vulnerable communities [7]. The complete protocol identifies the local food system and its constraints, and can be accomplished at the community level in six to eight weeks, the time being dependent on local infrastructure. These techniques can be used to characterize the perceptions and other factors influencing the harvest, preparation, preservation, and consumption of food sources of vitamin A that are essential to effect behavioural change to improve vitamin A status with food.

Field-tested in five developing areas where vitamin A is known to be a nutrition problem, the protocol was successfully implemented to give programme man-

TABLE 1. Research questions addressed locally

What are the key foods for vitamin A nutrition?	Availability, identification, acquisition, seasonality, cost, family members involved, nutrient content
How is food prepared and stored?	Preferred forms for sex and age, preparation technique, preservation technique, length of storage, nutrient content
What are cultural beliefs about key foods?	Attributes recognized, age and sex differences, perceptions and beliefs about vitamin A–rich food
What are the patterns of food use by women and children?	Pregnancy, lactation, infants, children 1–6 years of age Foods used, perceptions and beliefs about food effects
What are the beliefs and behaviours associated with vitamin A deficiency?	Local terms for night-blindness, corneal xerosis, corneal ulceration/keratomalacia, conjunctivitis When recognized, treatment sought, food given
Other issues?	Women's work, gardening, family food distribution, income control, common infections Health-agriculture-education programmes in place

agers key information to develop food-based strategies for vitamin A nutriture. The key questions locally addressed in the protocol are shown in table 1. Answers to these questions are critical to development of successful dietary approaches. A key surrounding issue is regional variation in local food systems and the availability and cultural acceptability of food. If food-based strategies are to be universally applied, these questions need to be addressed in the variety of environments and cultures in which vulnerable groups live, and commonalities need to be found.

The procedures in the protocol are shown in table 2. Details on how to complete the procedures are given in the protocol manual [7]. For identification of available food sources rich in vitamin A and provitamin A, the community food system data tables and market survey procedures are key elements of the procedure. The community food system data tables are completed for each food in the food system, and include information on local and scientific terminology, parts and preparation of the food, how it is harvested, seasonality of use, costs involved according to season, and importance to the community. They also include information, if it is known from national data, on nutrient composition. The market survey procedure includes information on food sources, seasonality, price range, price per serving, and price per 1,000 retinol equivalents (RE).

The key informant interview and mother-respondent interview procedures identify local perceptions and cultural constraints on the use of available food, which is information essential for programme planning.

These procedures, and the entire protocol, are intended as examples of information needed for effective programmes. Modifications and simplifications may be justified in some food systems where food availability and cultural constructs around food are known with certainty, or where information about multiple nutrients is an objective.

Food systems of indigenous peoples are those that are based on local food resources from the natural environment and are used by those whose culture evolved in an environment to provide all sufficient nutrients to sustain human life. Environmental change and economic development have brought dietary change to most indigenous groups in the world today. However, knowledge of the use of traditional food species remains within indigenous societies and can be documented for use in nutrition programmes. People in most traditional societies in developed and developing countries who live "close to the land" have good understanding of the usefulness of local species as food. However, this knowledge is not easily retained across generations when there is migration to new areas, particularly into urban settings. Thus, when seeking new food sources for vitamin A and provitamin A, it is often fruitful to search for information on uses of food species in rural areas long occupied by traditional societies. This research requires close collaboration with the people involved [8].

TABLE 2. Procedures in the protocol

» Background summary of area
» Interviews with 8–10 key informants
» Selecting key foods
» Community food system data tables
» Market surveys
» Interviews with 20–30 mother-respondents
  – Pile sort
  – Food attributes and differences
  – Rating food attributes
  – Food acquisition: where, when, who, cost
  – Frequency of food use: children, women
  – Health case scenarios
» Preparing the report

Examples of unique foods rich in vitamin A and provitamin A identified by research on traditional, local food systems

The field testing of the protocol revealed several excellent examples of unique foods rich in vitamin A. The team working in Sheriguda Village near Hyderabad, India, identified several examples of vegetables and fruits that were available and consumed. Of special note was *bachali* (*Basella alba)*, a creeping vine that is often grown for shade close to village homes. The leaves are evergreen and therefore available year-round [9]. Bachali is consumed after boiling and contains 2,480 µg of β–carotene per 100 g (table 3). Because of its glutinous texture after boiling, the plant is not universally liked, but it is acceptable when incorporated into other dishes.

The team working with the Aetas indigenous people in the Philippines found that the leaves of the sweet potato plant (*Ipomea batatas*) were often harvested to prepare for consumption by boiling or otherwise in soups and stews [10]. These leaves are also rich in provitamin A and were shown to contain 3,215 µg of β-carotene per 100 g (table 3). Worthy of note is the fact that several forest plant resources and fish harvested and consumed by the Aetas have not yet been scientifically identified, and no retinol or provitamin A values are available. In this community, major nutritional shortages appear to exist, including protein, zinc, and fat, thus further exacerbating vitamin A status.

The Hausas of Filingué in Niger commonly consume a street food called *kupta*, the major ingredient of which is horseradish tree leaves (*Moringa oleifera*). Kupta is prepared with the leaves as well as with ground peanuts and oil, thus making it a good food for preventing vitamin A deficiency [11]. The leaves contain 5,880 µg of β–carotene per 100 g (table 3).

TABLE 3. Traditional foods rich in retinol or carotene

Food source	Scientific name	Culture/location	Part used	Retinol or carotene content (per 100 g edible portion)
Bachali	*Basella alba*	India	Leaves	2,480 µg β-carotene
Talbos ng camote	*Ipomea batatas*	Aetas, Philippines	Leaves	3,215 µg β-carotene
Kunnen zogala ganda (for kupta)	*Moringa oleifera*	Hausas, Niger	Leaves	5,880 µg β-carotene
Sangre de carnero	*Ovis aries*	Peru	Blood	422 µg retinol
Narwhal	*Monodon monoceros*	Inuit, Canada	Blubber	1,700 µg retinol
Ooligan	*Thaleichthys pacificus*	Nuxalk, Canada	Grease	2,500 µg retinol
Canada goose	*Branta canadensis*	Cree, Canada	Grease	109 µg retinol

Sources: refs. 3 and 4.

In Cajamarca, Peru, rural and suburban Andean people access the local market where a good source of vitamin A is dried sheep's blood. Small packets of this product are purchased for addition to soups, stews, and gravies. Although it is not usually purchased by the very poor in the community, it is a resource that could be made more available with local management [12]. Dried sheep's blood is known to contain reasonable amounts of retinol, at 422 µg per 100 g (table 3).

Work with the traditional food systems and dietary status of the indigenous peoples of Canada has revealed three good sources of retinol that are notable here. With increasing dietary change, and decreased use of local, cultural food, dietary vitamin A has been consistently shown to be consumed below recommended levels [8], which has resulted in suggestions to increase the use of vitamin A–containing food. The first of these is the blubber of narwhal, a favourite food of the Inuit. Blubber is eaten in several forms, including the raw form after harvesting of this whale species (*Monodon monoceros*). Narwhal blubber is known to be an excellent source of retinol, with 1,700 µg of retinol per 100 g of blubber [13] (table 3).

On the west coast of British Columbia, several First Nations harvest the small smelt-like fish *Thaleichthys pacificus* in the early spring months for consumption in various forms (smoked, salted, boiled, and fried). In addition, a traditional fat is prepared after "ripening" the fish, simmering the fish in water, skimming the fat, and straining and reheating the fat. Although the raw fish are superior sources of retinol, the resulting fat or "grease" contains 2,500 µg of retinol per 100 g [14] (table 3). It is worthy of note that when the Nuxalk were living an entirely subsistence-level life, this fat was available at a critical time of the year, when fresh vegetable and plant foods were in very limited supply. This food is still used as a traditional medicine for various ailments, in addition to being used as a food condiment and frying medium.

A final example of a good source of vitamin A from a food system of indigenous people is Canada goose (*Branta canadensis*), which is harvested as a special cultural food by the James Bay Cree of Quebec in both the spring and fall goose hunts. The goose fat is rendered into a favourite food condiment called "goose grease" that is used in a variety of ways [15]. Preliminary results of retinol analysis show goose grease to contain approximately 109 µg of retinol per 100 g of fat (table 3).

Conclusions

These seven examples of unique local food resources containing substantial levels of vitamin A and provitamin A demonstrate that local food systems of those vulnerable to vitamin A deficiency need to be systematically investigated for foods that can be easily adopted into dietary strategies for the prevention of vitamin A deficiency. Identification of the food resources, their methods of preservation, and preparation for consumption, as well as knowledge of the amounts of the food consumed by vulnerable groups, must be recorded for their potential contribution to food-based programmes. Local food resources that are available and culturally acceptable are, logically, the best first choices for all nutrients.

References

1. Food and Agriculture Organization and International Life Sciences Institute. Preventing micronutrient malnutrition: a guide to food-based approaches. Washington, DC: ILSI Press, 1997.
2. Booth SL, Johns TA, Kuhnlein HV. Food sources of vitamin A and provitamin A. Food Nutr Bull 1992;14:3–33.
3. Booth SL, Johns TA, Kuhnlein HV. The complexities of understanding vitamin A in food and diets: the problem. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:11–28.

4. World Health Organization/UNICEF. Indicators for assessing vitamin A deficiency and their application in monitoring and evaluating intervention programmes. Geneva: WHO, 1994.
5. Kuhnlein HV, Pelto GH. Understanding vitamin A deficiency in the community. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:175–84.
6. Johns TA, Booth SL, Kuhnlein HV. Factors influencing vitamin A intake and programmes to improve vitamin A status. Food Nutr Bull 1992;14:20–33.
7. Blum L, Pelto PJ, Pelto GH, Kuhnlein HV. Community assessment of natural food sources of vitamin A: guidelines for an ethnographic protocol. Boston, Mass, USA, and Ottawa, Canada: International Nutrition Foundation for Developing Countries and International Development Research Centre, 1997.
8. Kuhnlein HV, Receveur O. Dietary change and traditional food systems of indigenous peoples. Annu Rev Nutr 1996;16:417–42.
9. Vazir S, Nayak U, Reddy V, Pushpamma P. India: the rural community of Sheriguda in Andhra Pradesh. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:161–71.
10. Santos-Acuin C, Gepte AT, Dedace MJ. The Philippines: the Aetas of Canawan during wet and dry seasons. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:55–68.
11. Blum L. Community assessment of natural food sources of vitamin A in Niger: the Hausas of Filingué. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:71–92.
12. Creed-Kanashiro H. Peru: the rural community of Chamis and the urban suburb of San Vicente in Cajamarca. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA: International Nutrition Foundation for Developing Countries, 1997:119–59.
13. Kuhnlein HV, Soueida R. Use and nutrient composition of traditional Baffin Inuit food. J Food Comp Anal 1992;5:112–26.
14. Kuhnlein HV, Yeboah F, Sedgemore M, Sedgemore S, Chan HM. Nutritional qualities of ooligan grease: a traditional food fat of British Columbia First Nations. J Food Comp Anal 1996;9:18–31.
15. Belinsky DL, Kuhnlein HV. Nutrient composition of Canada Goose (*Branta canadensis*), a traditional food resource of the Eastern James Bay Cree of Quebec. J Food Comp Anal (in press).

Food-based strategies to control vitamin A deficiency

Indira Chakravarty

Abstract

Vitamin A deficiency is still considered a major nutritional problem in the developing world. Increasing evidence of the role of vitamin A in the control of both morbidity and mortality is a point of great concern. Vitamin A supplementation began several years ago, and it still continues in many countries. However, there is a gradual realization that one of the most effective and sustainable ways to overcome vitamin A deficiency is through food-based strategies, which become a way of life. The most effective way to achieve this is by the following methods, in order of priority: dietary diversification (food supplementation, horticultural interventions, management of proper distribution, and availability of vitamin A–rich foods), nutrition education on all issues related to vitamin A (e.g., sources of vitamin A, importance of and need for vitamin A, methods of obtaining vitamin A–rich foods, and community involvement and participation in the process), and food fortification (identification of foods that can be fortified, development of proper cost-effective methods taking into account local food tastes and availability, and development of a mechanism to reach the most needy). This paper summarizes various case studies to ascertain the effectiveness of the different approaches.

Introduction

Vitamin A is an essential nutrient required in very small quantities to maintain normal health. It performs several critical functions in the body, including normal functioning of the eyes and protection of the body from disease and infection. Vitamin A is required to maintain the integrity of tissues lining the eyes, gastrointestinal tract, genitourinary tract, and respiratory system and to ensure optimal functioning of the immune system, growth, and development.

Prevalence of vitamin A deficiency

Vitamin A deficiency is a problem of public health significance in over 70 countries. It is prevalent in parts of most countries in Africa and Asia and in some areas of Latin America, the Caribbean, and the western Pacific [1]. It affects large numbers of pre-school and school-aged children and women of child-bearing age. Over 78 million children under five years of age are affected by vitamin A deficiency, putting them at risk in terms of their health and survival. About three million of these children have some form of vitamin A–related eye disease, ranging from night-blindness to irreversible partial or total blindness. The prevalence of clinical signs of vitamin A deficiency in developing countries was estimated to be about 0.6% in pre-school children in 1995. Clinical vitamin A deficiency is determined based on a combination of night-blindness and eye changes, predominantly Bitot's spots. In developing countries the prevalence of subclinical vitamin A deficiency, based on a serum retinol cut-off value of 0.7 µmol/L, ranges from 15% to 27%.

Sub-Saharan Africa and South Asia have a rate of clinical vitamin A deficiency of around 1% [2], double that of other regions. Subclinical vitamin A deficiency is also higher in these regions (table 1) [3, 4]. Table 2 shows the prevalence of night-blindness in pre-school children due to vitamin A deficiency in the six South-East Asia Region countries [5].

In a study conducted by the National Nutrition Monitoring Bureau [6] in 10 states of India, the prevalence of vitamin A deficiency was lowest in Kerala (0.3%) and highest in Madhya Pradesh (3.6%). Of the 40 districts surveyed, 34 reported a prevalence of Bitot's spots of at least 0.5%, indicating that vitamin A deficiency is a significant public health problem. In Indonesia children with vitamin A deficiency have been shown to be two to three times more prone to develop diarrhoeal

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TABLE 1. Prevalence of clinical and subclinical vitamin A deficiency among pre-school children in developing-country regions in 1995

	Clinical deficiency		Subclinical deficiency (range)	
Region	%	Millions	%	Millions
South Asia	0.95	1.58	19.2–35.6	32.3–59.5
East Asia and the Pacific	0.25	0.40	9.1–18.2	14.8–29.6
Latin America and the Caribbean	0.24	0.12	9.0–19.6	4.7–10.2
Eastern and Southern Africa	1.06	0.53	20.0–37.1	10.0–18.6
West and Central Africa	0.87	0.45	18.1–33.5	9.4–17.4
Middle East and North Africa	0.27	0.12	9.8	4.2

Sources: refs. 3 and 4.

and acute respiratory tract infections. These two diseases account for nearly half of childhood deaths in India.

Intervention strategies

Four main strategies are used to overcome micronutrient deficiencies: dietary diversification, food fortification, supplementation with vitamins and minerals, and public health and disease-control measures. Dietary diversification and food fortification are the two major food-based intervention strategies used to control vitamin A deficiency.

Dietary diversification by horticultural intervention

Horticultural intervention combined with extensive nutrition education is recommended as the major long-term and most sustainable food-based strategy to control and eliminate micronutrient malnutrition. Promotion of the consumption of carotene-rich food is a sustainable approach to combat vitamin A deficiency. Adequate production and consumption of carotene-rich fruits and vegetables, especially green leafy vegetables, play an important role. The South-East Asia Region countries are fortunately blessed with a wide array of inexpensive foods rich in provitamin A carotenoids.

TABLE 2. Prevalence of night-blindness among pre-school children in selected South-East Asia Pacific countries

Country	Prevalence (%)
Bangladesh	1.78
India	0.04
Indonesia	0.33
Myanmar	0.60
Nepal	0.60
Thailand	1.30

Source: ref. 5.

Traditional sources

Many fruits (mainly ripe yellow fruits such as mangoes, papayas, and tomatoes), vegetables, and tuber crops are rich sources of carotene. Leafy vegetables such as amaranth, beet leaf, palak, bassela, fenugreek, coriander, drumstick leaves, curry leaves, mint, and radish leaves are also rich sources of carotene. In general, the darker the green leafy vegetable, the higher its carotene content.

Non-traditional sources

Studies done by the All India Institute of Hygiene and Public Health in Purulia District of West Bengal showed that, apart from the well-known conventional green leafy vegetables, the leaves of a large number of plants growing wild in the countryside (which do not need specially tended kitchen gardens for their cultivation) are also good sources of β-carotene: for example, the leaves of many cole, root, and bulb crops such as cauliflower, cabbage, beets, and radish. These are usually discarded after the harvest of the main produce or sold at throwaway prices at the market. Six non-traditional herbs—arugampul, vilvam, tulasi, amaranth, drumstick, and spirulina—contain high levels of β-carotene, ranging between 5,500 and 84,000 μg per 100 g.

Home- and community-based gardening is now recognized as one of the approaches to increase the production and consumption of carotene-rich foods. One of its advantages is that it is culturally more appropriate and can provide multiple nutrients. Hence it may be a major contribution to an all-round nutritional development. Such approaches have been successfully adopted as a long-term strategy in several Asian countries. Vegetables selected for home gardening should have high nutritive value, be easy to grow and cook, and be palatable.

Case study of the horticultural approach

The All India Institute of Hygiene and Public Health conducted a pilot project in four villages of Purulia District, West Bengal, to test the effectiveness of home gardening coupled with nutrition education to combat the problem of vitamin A deficiency with support by the Food and Agriculture Organization (FAO) of the United Nations [7]. On the basis of the success of this pilot project, a project was initiated on the prevention of vitamin A deficiency through combined horticulture and education in nutrition and health, with the active help, cooperation, and support of the local government (the panchayat), for ensuring sustainability.

Study objective

The principal objective of the study was to prevent and reduce the prevalence of vitamin A deficiency by increasing the production and consumption of carotene-rich foods through locally feasible and acceptable horticultural methods and related nutrition education programmes. The producers were to be trained in improved horticultural methods suitable to local agroclimatic conditions, as well as in locally suitable methods of food preservation, seed preservation, nursery development, and seasonal production. For a program to be successful, there is a need to generate community awareness, involving women in particular, in the entire process. Ultimately, the impact needs to be assessed.

The project covered three widely dispersed blocks—Balarampur, Barabazar, and Hura—in Purulia District of West Bengal, which is the most drought-prone district of the country and has the highest tribal population. It included 1,500 households in 30 villages under three local panchayats where vitamin A deficiency was found to be endemic. The panchayat selected 15 volunteers, 5 in each block, to work for the project at the block level. The stages were collection of baseline data, intervention, and a resurvey to monitor and assess the impact.

Baseline data

The percentage of the population in the reproductive age group (44%) was greater than that in the post-reproductive age group (8%), indicating an expanding population. The sex ratio (989 females per 1,000 males) confirmed the national picture, that it was favourable to males.

According to weight-for-age classification, 14% of boys and 16% of girls under one year of age, 6% of boys and 5% of girls from one through three years of age, and 5% of boys and 5% of girls from four through six years of age were severely malnourished. Between 85% and 90% of the children had mild, moderate, or severe forms of malnutrition.

A height-for-age deficit indicative of chronic malnutrition was more prevalent in the 7- to 9-year and the 13- to 14-year age groups. Malnutrition assessed by mid-arm circumference was also seen in the zero to 3-year age group.

There were no clinical signs of vitamin A deficiency in children under one year of age; however, when all ages were combined, the prevalence was quite high (Bitot's spots, 3%; conjunctival xerosis, 6%; and night-blindness, 15%).

The clinical prevalence of vitamin A deficiency in lactating mothers was between 5% and 7%. Deficiencies of vitamin C (18.7%) and B_2 (15.3%) were noted in all age groups and in both sexes, as well as anaemia (28.5%), dental caries (22.2%), and calf tenderness (7%).

Quantitative diet survey data revealed that, compared with the recommended dietary allowances (RDA), the diets were adequate only in vitamins C, B_1, and B_2. The diets were deficient in protein (3%), fat (19%), calcium (19%), iron (48%), and carotene (30%). About 77% of the families had a deficient vitamin A intake (423 µg).

Rapid rural appraisals revealed that green leafy vegetables were available only during the rainy season and in winter. Fruits were a rare commodity, and pulses, meat, fish, eggs, and milk were consumed only occasionally. The prevalence of night-blindness was high, particularly among mothers. Breastfeeding was universal and was continued until the infant was two to three years old. The survey communities had food taboos, particularly during certain physiological conditions, such as pregnancy, lactation, and illness.

Knowledge, attitude, and practices with regard to vitamin A foods and vitamin A deficiency were very poor.

Intervention

To ensure support from the community and from the local and state governments, a State-Level Advisory Committee chaired by the Honorable Minister, a District-Level Committee chaired by Sabahdhipati Zila Parishad, and Block/Village Level committees in each of the three blocks were formed. Community volunteers were selected to conduct activities of the project at the household level.

The field staff of the Institute and the community volunteers were trained in the objectives and purpose of the study; the schedule for data collection and concepts behind these data; the International Vitamin A Consultative Group method of assessment of vitamin A intake; collection of information about knowledge, attitudes, and practices; home gardening methods; and communication of nutrition messages to the public, particularly to mothers. A core group of trainers was created at the village level to maintain continuity.

Local governments and functionaries provided land for six nurseries, two in each of the three blocks, that were used to grow plants and supply seeds to the community. Water sources (including wells and pumps) were also provided. The local communities provided the labour, and local extension workers, Integrated Child Development Service and public health centre staff, and panchayat workers assisted with the coordination of the programme.

Health and nutrition education was provided to the volunteers and fieldworkers by experts from the All India Institute of Hygiene and Public Health, Vishwa Bharati University, Jadavpur University, the State Planning Board, the Government of West Bengal, the Parliamentary Committee on Health, and FAO experts. The trainees subsequently acted as trainers.

The following nutrition education and training materials were prepared and disseminated: a handbook on home gardening methods for growing vitamin A–rich vegetables and fruits; a functional education booklet on the importance of vitamin A in the diet; a manual for the elected panchayat leaders on the planning and implementation of the project, indicating their responsibilities to achieve the objectives of the project; a leaflet on the types and importance of vitamin A–rich vegetables; audio cassettes containing songs for promoting consumption of vitamin A–rich vegetables and their role in the prevention of vitamin A deficiency; video cassettes on methods of growing different fruits and vegetables, specifying land requirements, seeds and plants, timing, inputs, cost, etc.; video cassettes on vitamin A deficiency and how to control it; and a crop calendar for vitamin A–rich vegetables.

The project provided the beneficiaries with seeds, fertilizer, gardening equipment, and training on better cultivation practices for production in the home garden. Six central nurseries were established to produce seedlings for distribution by the panchayat to the project beneficiaries at a nominal cost. The land for the nurseries was provided by the panchayat. Food technologists provided training on the preservation of fruits and vegetables as well as suitable technology for local food fortification.

Impact

A baseline study and a post-project survey were conducted to assess the impact of the intervention.

Production of green leafy vegetables

The percentage of households cultivating green leafy vegetables increased in all three blocks compared with baseline: from 82% to 94% in Balarampur, from 78% to 94% in Barabazar, and from 84% to 97% in Hura. The production of all vegetables (green leafy and other vegetables) increased. An increased number of households felt that the cultivation of papaya and green leafy vegetables should be increased.

The most remarkable change was that each household attempted to grow at least one drumstick plant to provide drumstick leaves throughout the year and at least one creeper (pumpkin, gourd, or poi) on the rooftop.

Consumption of green leafy vegetables

The weekly consumption of green leafy and other vegetables at the household level increased substantially to more than three times a week. The consumption of green leafy vegetables increased in the three areas compared with baseline: from 20% to 50% in Balarampur, from 17% to 40% in Barabazar, and from 15% to 45% in Hura. The average intake of greens increased by 15 g/day/ACU (average consumption unit).

The average consumption of fruits rich in carotene increased by as much as 7.5 g/day/ACU in the form of ripe papaya and mango, which were in season at the time of the survey.

Economic benefit of kitchen gardens

There was a direct economic benefit of the kitchen garden. In addition to growing enough for their own consumption, a high percentage (40%) of families sold about 10% to 25% of the produce.

Prevalence of signs and symptoms of vitamin A deficiency

The prevalence of signs and symptoms of vitamin A deficiency was reduced: conjunctival xerosis from 6.4% to 3.5%, Bitot's spots from 2.8% to 0.8%, and night-blindness from 15.3% to 4.7%.

Knowledge, attitudes, and practices

The knowledge that night-blindness was caused by vitamin A deficiency increased from 15% to 36% in Balarampur, from 8% to 26% in Barabazar, and from 5% to 40% in Hura. There was also an increase in the awareness of the value of including green leafy vegetables in weaning food for infants from 35% to 45% in Balarampur, from 39% to 63% in Barabazar, and from 45% to 67% in Hura.

The most common reason given by respondents for increasing vegetable production was their good nutritional value as food. The knowledge that both green leafy vegetables and yellow fruits are good sources of vitamin A increased from 36% to 47% in Balarampur, from 25% to 31% in Barabazar, and from 40% to 49% in Hura.

Community needs and demands

That the community was highly motivated was proven by several facts. The community was inclined to grow more greens. There was a demand for high-yielding, drought-resistant varieties of seeds from the local coordinators. Women requested more cooking demonstrations, and when volunteers and experts visited them they asked relevant questions regarding cooking practices for better availability of nutrients. There was continuous demand to teach and support methods to preserve seasonal produce. Panchayat leaders and workers were requested to provide continuous health and nutrition education, particularly to illiterate women through visual aids.

Involvement of the panchayat

The entire panchayat from the district to the village level was highly motivated about the usefulness of home gardening for the alleviation of malnutrition due to deficiency of vitamin A as well as other micronutrients, such as vitamin C, iron, and folic acid. There was excellent cooperation between the workers and the villagers during the whole course of the study. The success of the study largely depended on the coordinated approach with the people's participation. The local panchayat leaders and workers demanded further extension of the programme, at least in respect of information for home gardening, creation of nurseries, and continuous health and nutrition education, so that the people could be more knowledgeable as well as motivated.

Audiovisual aids

The impact of posters, pamphlets, and booklets on literate people, panchayat workers and leaders, and primary school teachers was impressive. They discussed vitamin A malnutrition and its prevention knowledgeably with the experts visiting them. Musical and video cassettes impressed the illiterate women, particularly those who responded most to all the interventions initiated.

Sensitization, advocacy, and reorientation meetings and training

Various meetings, training programmes, and field-level seminars were conducted to draw the attention of authorities and workers from all levels, such as local members of the Legislative Assembly, Sabhadhipati, panchayat Pradhan, local leaders, and non-governmental organization leaders. The workers and volunteers who were trained in various aspects of the project were found to deliver services most effectively at the household levels not only in the project area but also beyond it, according to the request of the local panchayat. However, the most important feature was the enthusiasm and eagerness of the local villagers, particularly the women.

Follow-up

A meeting to share project objectives, activities, and results was held on the floor of the Assembly House of the Government of West Bengal with senior Ministers of the state, including the Minister of Planning and Development, all elected members of the Legislative Assembly, panchayat leaders, and national as well as international consultants and experts. After thorough discussion, the House recommended the initiation of similar programmes on home gardening in other districts and its inclusion in the state plan. They also recommended that a certain percentage of the panchayat budget should be reserved for it.

Other case studies of horticultural intervention from the region

Andhra Pradesh, India

The National Institute of Nutrition conducted a three-year study to assess the feasibility of home gardening in 20 villages in two agroclimatic regions in one of the South Indian states [8]. After a baseline survey, seeds and seedlings of carotene-rich foods were distributed, along with multimedia nutrition education. An evaluation revealed that there was a more than a sixfold increase in the percentage of households with home gardens. About 65% of these households were growing seasonal greens, such as amaranth and spinach, in addition to perennials, such as drumstick, papaya, and bachali. The frequency of consumption of carotene-rich foods (more than once a week) increased by about 50% over that observed at baseline. About 50% of the people in households with surviving drumstick plants consumed the leaves, as compared with none at baseline. The prevalence of Bitot's spots showed a declining trend, although it was not statistically significant ($p > .05$), with increasing duration of participant. This study clearly indicated that the home gardening approach is feasible and can be an essential long-term strategy to combat vitamin A deficiency in rural India, and pointed out the need to add nutrition to the current horticultural programmes in India.

Maharastra, India

A study in the urban slums was undertaken by Srimati Nathibsbai Damodar Thackersey University in Bombay [9]. The study indicated that there is great potential to promote the production as well as the consumption of vitamin A–rich foods among urban slum dwellers despite space, financial, and other constraints.

Bangladesh

A home-gardening evaluation study prepared by Helen Keller International in Bangladesh showed there was an increase in the consumption of garden produce, a more than 25% increase in household vegetable consumption, a reduction in the prevalence of night-blindness, and an improvement in overall household food security.

Another study of home-gardening projects in an urban setting in Bangladesh showed an increase in the percentage of households with gardens from 0.7% to 9.4%*. Even more encouraging was the increase in con-

* Talukder A, Tabibul AK, Das S, Baker SK, Bloem MW, Kiess L. Home gardening in urban settings: experiences from HKI Bangladesh. XVIII International Vitamin A Consultative Group Meeting, Cairo, 1997.

sumption of vegetables by children under six years of age.

In another study in Bangladesh, children from households with a homestead garden were 29% more likely to consume green leafy vegetables**. In addition, market dependency for green leafy vegetables at the household level decreased with improvements in gardening practices, and the frequency of consumption of green leafy vegetables by children increased accordingly, i.e., the association between the type of household garden and child nutritional status was strong.

Worldview International Foundation conducted a study in the high-risk areas of the Greater Rangpur-Dinajpur Region in northern Bangladesh [10]. The results demonstrated that 1,010 school gardens, 50,500 student gardens, and 975,283 home gardens were developed. The prevalence of night-blindness per 100 households decreased from 5.37 in the 1987 baseline survey to 3.23 in the evaluation survey in 1990. Ninety-five percent of the respondents knew the correct meaning of night-blindness. Over 90% of the parents knew the age of occurrence of night-blindness, and 84% were aware that night-blindness could be prevented by eating vegetables and fruits.

Vietnam

A community nutrition project conducted in four communes of Vietnam included 5,588 households with 3,716 young children [11]. There were significant increases in the production of fruits, vegetables, and other foods from family gardens. An increased intake of nutrients, including iron, vitamin C, carotene, and protein, among households with young children was observed. There were improvements in the nutritional status of young children and the nutritional knowledge of their mothers. Mothers who had participated in the pilot nutrition education programme demonstrated a significantly better understanding of good nutrition and of vitamin A than those in the control group.

Thailand

The prevalence of Bitot's spots in Thailand was significantly reduced by the use of modern communication techniques in social marketing to promote consumption of carotene-rich foods [12]. The local health system and other allied departments were also actively involved.

Indonesia

Orange fruit was found to be more effective than green leafy vegetables in increasing serum concentrations of retinol and β-carotene in Indonesian schoolchildren [13].

Food fortification

Nutrient fortification of staple foods was developed in the early part of the twentieth century. Salt was iodized in Switzerland in the early part of the century. During the 1930s and 1940s, milk was fortified with vitamin A and flour was fortified with iron and B vitamins in a number of European countries and North America. Margarine fortified with vitamin A was introduced in Denmark in 1981.

The technology of food fortification holds forth an affordable and immediate opportunity for developing countries, particularly India, to improve lives and accelerate social and economic development, provided it can reach the most deprived and needy. Today, in developed countries where there is a high dependence on processed food and industries are streamlined and automated, food fortification has played a major role in the health of the population at large. It provides the maximum benefit for the minimum investment. In other words, it is probably one of the most efficient as well as one of the most cost-effective means of eliminating micronutrient malnutrition. For developing countries, however, suitable developments and modification need to be worked out. Cost control has to be effective, otherwise fortification is not likely to have an impact on the most vulnerable groups.

One or more nutrients that are normally absent or otherwise present only in minimal amounts can be added to a food. The amount to be added has to be designed to contribute significantly towards the improvement of the nutritional status with respect to that nutrient. However, this will need careful monitoring, considering the fact that there is a wide variation in the intake pattern within the community. For the programme to be successful, the fortified staple food must reach everyone, especially the deprived and vulnerable population.

Fortification is socially acceptable, requires no change in food habits, and does not change the characteristics of the food. It can be introduced quickly and has readily visible benefits. It also can be legally enforced, is relatively easy to monitor, is safe, and is the cheapest intervention for any country. What is required is commitment from the government and the food industry and a suitably informed consumer who demands a micronutrient-rich food.

A staple food suitable for fortification should be consumed by a sizeable proportion of the target population; be processed centrally in large enough quantities

** Loganathan R, Huq N, Burger S, Kirwan MFA, Hye A, Khan SR, Baker SK, Kiess L. Consumption of green leafy vegetables among children from households with homestead gardens in rural Bangladesh. XVIII International Vitamin A Consultative Group Meeting, Cairo, 1997.

to allow controlled fortification; be distributed through a widespread network so that it reaches all regions of the country; be inexpensive, so that it can be consumed by all income groups; not change in taste, colour, or appearance on fortification; not lose the nutrient on further processing or cooking; and have a stable and uniform per capita daily intake, so that the fortification levels can be accurately assessed. The added nutrient should be physiologically available from the food. It should supply optimal amounts without increasing the risk of excessive intake or toxic effects. It should not have inhibitors such as phytates; if inhibitors are present, suitable corrective methods will have to be adopted. Fortification should be economically feasible through an industrial process. The end product should not cost significantly more than the dietary vehicle or the unfortified product. The fortified product should be stable, and if a pre-mix is used, it should mix well with the dietary vehicle and not separate from it.

Fortification of oil and vanaspati with vitamin A

In India the per capita annual availability of edible oils and vanaspati (all-purpose cooking fat or vegetable ghee) increased from 4.7 kg in 1980 to 7 kg in 1994. The availability of vanaspati remained unchanged at 1 kg, but that of edible oil increased from 3.7 to 6 kg. About 0.9 million tons of vanaspati are produced in India annually. The production of vegetable oil doubled between 1985 and 1995. Oil is still imported, mainly as palm olein from Malaysia. The palm oil is reprocessed and clarified, eliminating the β-carotene.

Although it is mandatory in India for vanaspati to be fortified with vitamin A to a level of 40% of the RDA, the efficacy of this measure and its benefits to the low-income groups are yet to be clearly established. The rural population consumes very little vanaspati (0.3 to 1 g per day) and therefore receives very little vitamin A through this vehicle. Increasing the per capita income in rural areas and selling vanaspati in smaller, affordable packages may contribute to its higher consumption.

A survey indicated that the average daily consumption of vanaspati is higher in the higher-income group (10 g), resulting in vitamin A availability of 250 IU, or 12.5% of the RDA. The urban population consumes between 3.5 and 17 g per day, but there is wide regional variation, with those in the south consuming less than those in the north. Moreover, a sizeable amount of vanaspati is lost on heating.

However, it is important to ensure that there is either no or very little cost increase, since any sizeable cost increase will affect the domestic market and may allow greater penetration by imports. It is significant in this context that a value-added fortified oil product launched recently has not met with the expected success. Another suggestion that has been mooted is that the fortification can be implemented when the oil is unloaded and repackaged. However, this may also lead to unwanted adulteration unless a stringent monitoring process is built in. Moreover, since fried foods are popular in India, retention of the vitamin A in the oil after repeated heating needs to be tested before launching a national initiative.

The Philippines mandates the fortification of margarine. Shelf-stable margarine with 375 retinol equivalents (RE) of vitamin A per 15-g serving has been on the market since 1993. Within six months of its introduction there was a 6% decrease in the prevalence of low serum retinol, since margarine is a widely used product.

Milk and dairy products

In India 65 dairies have fortified their liquid milk with 2,000 IU of vitamin A per litre. The effort was supported by a government subsidy to meet the additional costs of fortification for three years. After the subsidy was withdrawn, the dairies were reluctant to pick up the fortification costs. A possible contributing factor may be the lack of generation of awareness and consequently the absence of any public demand or outcry from the consumers. There is also scope for fortifying the powdered milk often used in public feeding and Integrated Child Development Service programmes.

Sugar

Sugar production was introduced in India in 1906. The average annual production is 12 million metric tons. Thirty-six percent of the white sugar is used mainly in soft drink factories, 24% is sold in the free market for domestic use, and 40% is purchased as levy sugar (with the smallest crystal size and the least white colour). The refined sugar industry is well organized, and fortification with micronutrients may be feasible in a controlled manner. However, the wide variation in intake among various groups, and particularly the fact that members of the lower-income groups, who need micronutrient support the most, consume very little sugar, raises speculation as to its use as a fortification vehicle.

In the mid-1960s, Guatemala was identified as a country where a relatively large proportion of the population under 15 years of age had vitamin A deficiency [14]. Sugar was identified as a centrally processed foodstuff that was widely consumed by children at risk of deficiency and that could be fortified with vitamin A. Sugar was first fortified on a large scale in Guatemala in 1974. In the same year, the Guatemalan Congress enacted a law requiring all sugar produced for the domestic market to be fortified with vitamin A. Sugar was initially fortified during a two-year period, and the subsequent epidemiological surveys among pre-school children revealed a significant positive impact. All refined sugar in Guatemala is currently fortified with vitamin A at approximately 50 IU per gram. It is estimated that children receive about 70% of their vitamin A requirements from sugar. The Guatemala programme has had an important impact on both the vitamin A and the anaemia status of Guatemalan children and may have contributed to the decrease in child mortality rates.

This approach could be adopted in Asia, considering the consumption pattern (which has wide variations), the cost, and the overall legal control mechanism.

Rice

Since rice is the main dietary staple in many regions where vitamin A deficiency is prevalent, it is a suitable vehicle for fortification. A process has been developed to fortify rice with vitamin A and other micronutrients. The product is known as Ultra Rice. Ultra Rice is manufactured by blending the fortificant into rice flour and extruding the resulting paste to yield a concentrated, fortified rice product that has the appearance, density, and taste of unfortified rice [15]. The concentrate, with a typical vitamin A content of approximately 2,500 IU/g, can be blended with unfortified rice at ratios from 1:100 to 1:200 to provide an appropriate dietary level of vitamin A. The size and shape of the concentrated grain can be adjusted to match the type of rice being fortified. The source of the rice flour can be milled or broken rice grains, which account for 15% to 50% of the world's rice harvest, depending on the region. However, its acceptance, cost at the household level, and availability are important factors that need to be considered.

Guidelines for developing a food fortification strategy for India

The health, food, and industry sectors need to work together closely, with an explicit understanding and recognition of one another's viewpoints, concerns, and interests. Food fortification provides a unique opportunity for the food industry and trade to participate and play a leading role in a health intervention endeavour.

The regulation of food quality through legislation and its effective enforcement will greatly contribute to the success of fortification efforts. Fortification efforts should be supplemented by and combined with other intervention strategies, such as supplementation, dietary approaches, nutrition education, and social marketing. The programmes should dovetail into India's existing food production and distribution systems with minimum disruption or cost. Subsides, especially in the case of iron fortification, may help reduce the cost to consumers and help the fortified product gain popularity and widespread acceptance.

An effective and sustainable micronutrient delivery system necessitates a multisectoral approach involving government, industry, the scientific community, and consumer groups in its planning and monitoring. The expertise available in the industry for market development and price determination needs to be tapped. The free-market, profit-oriented approach of industry should be supported.

The technical feasibility of the fortification process needs to be carefully analysed and evaluated. The process should not in any way affect or alter the vehicle, and the nutrient losses during storage and cooking should be within tolerable limits. There should be active involvement of industry in developing the technology and in production and quality control. Research and development facilities in large multinational companies may be of help in this regard.

A social marketing approach needs to be effectively harnessed to generate an increasing awareness of the problems associated with micronutrient deficiencies and the need to consume fortified foods.

The people operating at various levels of the public and private sectors need to be appropriately trained in the techniques of food fortification, quality control, monitoring, and evaluation. Monitoring and evaluation is an essential and integral component of the programme, which helps us to identify the process, problems, and needs. The food quality and fortificant levels in the foods at various levels from production to consumption need to be measured to ensure that the population is receiving adequate quantities of the nutrient. Periodic estimation of the clinical and biochemical indicators is also essential to evaluate the impact of the intervention approach.

The development of multiple fortification programmes needs to be well coordinated. Considering the limitations in the available technology, there is need for more extensive and coordinated research and development. Field and pilot commercial trials may be required to evaluate the technical and economic feasibility and consumer acceptability of the product.

The experiences of other countries, agencies, and industries need to be strengthened to select the most viable and sustainable mechanism for India. Care has to be taken that fortification does not lead to increased cost, an open door for adulteration, an inability to reach the most needy, or an excess intake of a particular component.

References

1. Cervinskas J, Houston R. Monitoring vitamin A programmes. Ottawa, Canada: Micronutrient Initiative, 1998.
2. MI/UNICEF/Tulane University. Progress in controlling vitamin A deficiency. Ottawa, Canada: Micronutrient Initiative, 1998.
3. WHO. Global prevalence of vitamin A deficiency. Micronutrient Deficiency Information System (MDIS) Paper No. 2 (WHO/NUT/95.3). Geneva: World Health Organization.
4. WHO/UNICEF/International Vitamin A Consultative Group. Vitamin A supplements: a guide to their use in the treatment and prevention of vitamin A deficiency and xerophthalmia. Geneva: World Health Organization.
5. WHO. Health situation in the South-East Asia region 1991–1993. Geneva: World Health Organization, 1995.
6. National Nutrition Monitoring Board. Report of NNMB surveys of nutritional status of rural populations. Hyderabad, India: National Institute of Nutrition, Indian Council of Medical Research, 1996.
7. Chakravarty I, Cainet C. Street foods in Calcutta. Food Nutr Agric 1996;17/18:30–7.
8. Vijayaraghavan K, Nayak MU, Bamji MS, Ramana GNV, Reddy V. Home gardening for combating vitamin A deficiency in rural India. Food Nutr Bull 1997;18:337–43.
9. Task force for horticulture division. Increasing production of vitamin-A rich horticulture crops. Krishi Bhawan, New Delhi: Ministry of Agriculture, Government of India, 1996.
10. Worldview International Foundation. Comprehensive nutrition and blindness prevention programme. Dhaka, Bangladesh: Worldview International Foundation, 1995.
11. English R, Badcock J. A community nutrition project in Viet Nam: effects on child morbidity. Food Nutr Agric 1998;22:15–21.
12. Smitasiri S, Attig GA, Valyasevi A, Dhanamitta S, Tontisirin K. Social marketing vitamin A rich foods in Thailand. Salaya, Thailand: Institute of Nutrition, Mahidol University, 1992.
13. de Pee S, West CE, Permaesih D, Martuti S, Muhilal, Hautvast JG. Orange fruit is more effective than are dark green, leafy vegetables in increasing serum concentrations of retinol and β-carotene in school children in Indonesia. Am J Clin Nutr 1998;68:1058–67.
14. Raphael A. Sugar fortification in Guatemala. New York: UNICEF, 1994–1995.
15. Flores H. Bioavailability of vitamin A in a synthetic rice premix. J Food Sci 1994;59.

Red palm oil in the maternal diet improves the vitamin A status of lactating mothers and their infants

L. M. Canfield and R. G. Kaminsky

Abstract

Improvement of the vitamin A status of lactating mothers and their nursing infants following maternal palm oil consumption was comparable to that following supplementation with purified β-carotene. Mothers who consumed β-carotene as red palm oil had 2.1- and 2.5-fold increases in their serum and milk β-carotene concentrations, respectively, and 2.8- and 3.2-fold increases in their serum and milk α-carotene concentrations, respectively. Infant serum retinol concentrations were significantly increased following maternal supplementation with red palm oil or β-carotene. Maternal intake of red palm oil or β-carotene supplements did not alter infant serum carotenoids, maternal serum retinol, or milk retinol. Because the local diet includes foods prepared with oil, the possibility that red palm oil could provide a significant source of provitamin A carotenoids for Honduran women and children should be further investigated.

Introduction

On the basis of meta-analysis of intervention trials conducted over the past decade, it is estimated that vitamin A supplementation can reduce childhood mortality in developing countries by as much as 30% [1]. However, in spite of widespread vitamin A supplementation programmes in these countries for more than two decades, vitamin A deficiency remains a major problem because of logistical and economic obstacles to their implementation [2]. It is estimated that in a single year, vitamin A deficiency still contributes to over one million childhood deaths and is responsible for blindness in about half a million children. In response to this problem, the World Bank has recommended fortification of common foods as an additional strategy [3]. A number of options are currently being investigated, including biscuits fortified with β-carotene [4], dietary palm oil [3, 5], and β-carotene-containing foods [6–9].

We have previously demonstrated [10, 11] that supplementation of mothers with β-carotene results in a substantial increase in serum carotenoids in maternal serum and milk. In addition, others have reported that vitamin A supplementation of mothers improves the vitamin A content of breastmilk and the vitamin A status of nursing infants [12]. Building on these results, we investigated the effect of supplementing lactating mothers who were low in vitamin A with β-carotene or red palm oil. Our hypothesis was that increasing the provitamin A intake of the mother with foods high in β-carotene or with β-carotene-fortified foods can increase the vitamin A content of maternal milk, thus improving the vitamin A status of the mother–infant pair.

Although they are not currently marketed in Honduras, red palms are grown commercially on the north coast of Honduras and therefore are potentially accessible to the Honduran population. Staples of the Honduran diet, such as plantains and black beans, are typically prepared with oil. Furthermore, in spite of early concerns about atherogenicity, it is now clear that red palm oil is no more atherogenic, and possibly less so, than other plant oils [13–15]. In addition, red palm oil is a rich source of energy and vitamin E as well as of α-carotene, which is also a provitamin A carotenoid. Therefore, we chose red palm oil as a vehicle for our studies with the hope that introduction of this oil into the diet of mothers could eventually contribute substantially to a sustainable solution to vitamin A deficiency in Honduras.

Methods

Studies were conducted from November 1993 through June 1997 in three colonias (urban districts) near

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

Tegucigalpa: Via Cristina, Los Pinos, and Via Alemania. The methods of the first two studies have been described in detail elsewhere [16, 17]. The design of the Via Alemania study was similar to that of the other two, except that it was carried out over one month. The total amount of β-carotene supplement provided in each of the studies was 90 mg.

Subjects

Lactating mothers and their nursing infants (aged 1–24 months) were recruited from the marginal barrios of Tegucigalpa. Mothers provided informed consent in accordance with the regulations of the University of Arizona Human Subjects Committee. Mothers who smoked, were ill, had infants with chronic illnesses, or had infants less than one month old were excluded from the study.

Immediately after their arrival in the clinic, health histories for mothers and infants and 24-hour dietary recalls were obtained from the mothers. Supplements were administered with a breakfast that provided about 8 g of fat. The meal consisted of tortillas, black beans, *crema* (a local sour cream product), and 250 ml of whole milk. The β-carotene supplements were provided as capsules (BASF), beadlets (Hoffmann LaRoche), or red palm oil. The β-carotene concentrations of the supplements were verified by high-performance liquid chromatography (HPLC). Milk was obtained from the mothers at mid-morning by manual expression. Blood samples were obtained from the mothers and infants by a trained, Spanish-speaking phlebotomist using venipuncture.

Sample collection and handling

The blood samples were transported to a clinical laboratory in Tegucigalpa where serum was prepared and stored at –20°C along with milk samples. The frozen milk and serum samples were hand-carried by air to the laboratory in Arizona by one of the research staff. On arrival in Tucson, the samples were stored at –70°C until they were analysed. Carotenoids and retinol were analysed in serum and milk by HPLC, as previously described [11, 18]. The lipid content of the milk was determined as the percentage of the total volume by creamatocrit assay [19].

Dietary analyses

Because the diets of the mothers contained very few foods high in carotenoids, and because only limited information on individual carotenoids was available for Honduran foods, a qualitative rather than a quantitative analysis of the diets was performed. Serving sizes were recorded by volume (e.g., ½ cup of vegetables, ½ cup of milk or ice cream), piece (e.g., one piece of fruit), or weight (e.g., 100 g of meat).

Statistical analysis

Standard descriptive statistics were performed using Microsoft Excel 5.0 or STATA (College Station, Tex., USA).

Results and discussion

The results of three studies from our laboratory designed to determine the effect of β-carotene supplementation of lactating mothers on the vitamin A status of the mother–infant pair are shown in tables 1 to 3. Supplementation of lactating mothers with β-carotene or dietary red palm oil significantly increased their serum and milk β-carotene levels and the serum retinol levels of their nursing infants. The total dosage of β-carotene administered in all studies was 90 mg. Since the duration of the studies varied from 5 to 30 days (table 4), in a strict sense they cannot be directly compared. However, the results clearly demonstrate that the effectiveness of red palm oil is comparable to that of β-carotene supplements in improving the vitamin A status of lactating mothers and their infants.

Maternal diets were monotonous, consisting mostly of beans and tortillas, with an occasional serving of meat and dairy products. The diets were extremely low in fruits and green vegetables. Dietary data for the Via Cristina and the Los Pinos studies have previously been

TABLE 1. Changes in β-carotene concentration of mothers' serum

Study	Supplement	Concentration (μmol/L ± SEM) Initial	Final	Fold increase
Via Cristina	β-Carotene beadlets	0.09 ± 0.05	0.88 ± 0.39[a]	9.7
Los Pinos	BASF β-carotene	0.21 ± 0.01	0.26 ± 0.02[b]	1.2
	Palm oil	0.32 ± 0.39	0.67 ± 0.06[a]	2.1
Via Alemania	β-Carotene beadlets	0.28 ± 0.11	0.76 ± 0.35[a]	2.7

a. $p < .01$ (paired, two-tailed *t* test).
b. $p < .05$ (paired, two-tailed *t* test).

TABLE 2. Changes in β-carotene concentration of breastmilk

Study	Supplement	Concentration (μmol/L ± SEM)		Fold increase
		Initial	Final	
Via Cristina	β-Carotene beadlets	17.0 ± 1.90	99.0 ± 16.6[a]	5.8
Los Pinos	BASF β-carotene	38.9 ± 17.3	64.1 ± 31.9[a]	1.6
	Palm oil	35.3 ± 15.5	88.4 ± 37.7[a]	2.5
Via Alemania	β-Carotene beadlets	23.9 ± 24.3	72.6 ± 39.1[a]	3.0

a. $p < .001$ (paired, two-tailed *t* test).

TABLE 3. Changes in retinol concentration of infants' serum

Study	Supplement	Concentration (μmol/L ± SEM)		Absolute increase (μmol/L)
		Initial	Final	
Via Cristina	β-Carotene beadlets	0.88 ± 0.28	1.02 ± 0.25[a]	0.14
Los Pinos	BASF β-carotene	0.71 ± 0.06	0.74 ± 0.04	0.03
	Palm oil	0.64 ± 0.03	0.74 ± 0.04[a]	0.10
Via Alemania	β-Carotene beadlets	0.48 ± 0.16	0.55 ± 0.13[a]	0.07

a. $p < .01$ (paired, two-tailed *t* test).

TABLE 4. Outline of study protocols

Feature	Via Cristina	Los Pinos	Via Alemania
Supplement	β-Carotene beadlets[a]	β-Carotene capsules[b] Red palm oil[c]	β-Carotene beadlets[a]
β-Carotene dosage	3 × 30 mg	6 × 15 mg	12 × 7.5 mg
Treatment days	1, 3, 4	1, 3, 5, 7, 9, 10	1, 14
Sample collection days	1, 3, 5	1, 10	1, 14, 30
Duration of study (days)	5	10	30
No. of subjects			
Mothers	43	32 palm oil 36 β-carotene	42
Infants	25	26 palm oil 26 β-carotene	30

a. The supplement was provided by Hoffmann LaRoche.
b. A powdered preparation of β-carotene (BASF, 15 mg), dispersed in cornstarch and packaged in an opaque capsule. β-Carotene concentrations in the BASF preparation were verified by HPLC.
c. The red palm oil fraction (Palm Oil Research Institute of Malaysia) contained 0.55 mg of β-carotene and 0.25 mg of α-carotene per milliliter. We estimated that the effective amount of provitamin A carotenoid furnished by α-carotene in palm oil was < 2 mg (12.5% of the total dose); this amount was not considered in the calculations.

described in detail [16, 17], and the diets in the Via Alemania study were similar to these. For example, in the Via Alemania study a third of the women reported consuming no fruits or vegetables in the 24 hours before completing the questionnaire. Further, although vitamin A consumption was very low, most of it, surprisingly, was in the form of retinol from animal sources or fortified foods, not in the form of provitamin A carotenoids. In Honduras the sugar supply has been fortified with vitamin A since 1993; however, the extent of industry compliance is unclear at present [20]. Although oil is used for cooking, lard is the most common fat used for cooking. However, foods prepared with oil are widely consumed. Oils containing carotenoids, such as red palm oil, are potentially effective vehicles for increasing vitamin A intake in this population of mothers and infants.

Changes in maternal serum β-carotene concentrations following the various treatments are shown in table 1. The initial concentrations of serum carotenoids were substantially lower than those of mothers in the United States [10, 11, 18]. The largest changes were in response to β-carotene beadlets in the Via Cristina study, where the initial concentrations were lowest (approximately 10% of those of mothers in the United States). Since this study was conducted in winter and the others in spring, seasonal variation may have been responsible, at least in part, for the noticeably lower maternal serum and milk carotenoid concentrations. Interestingly, infant serum retinol concentrations were not lower than those in the other studies, suggesting that maternal carotenoid stores are mobilized to provide a vitamin A source for the infant.

The smallest changes in serum carotenoids were in response to the powdered β-carotene preparation, apparently due to its lower bioavailability compared with that of water-miscible beadlets [21]. Notably, palm oil treatments compared favourably to beadlets when the starting serum concentrations were the same, despite the difference in duration of supplementation. In this regard, no further increase was seen after day 3 (60 mg dosage) in the Via Cristina study or day 14 (45 mg) in the Via Alemania study, suggesting that a maximum increase is reached within a few days.

The other major carotenoids we analysed, α-carotene, β-cryptoxanthin, lycopene, and lutein/zeaxanthin, were unaffected by any of the β-carotene treatments. Similarly, the concentrations of β-cryptoxanthin, lycopene, and lutein/zeaxanthin were unaffected by palm oil treatments. However, serum α-carotene was increased almost threefold in mothers and 1.4-fold in infants [17]. Maternal serum retinol concentrations were not affected by any of the treatments.

Changes in milk β-carotene are shown in table 2. As in the case of serum β-carotene, the β-carotene beadlets in the Via Cristina study produced the largest increases. Similarly, the initial milk carotenoid concentrations of mothers in the Via Cristina study were substantially lower than in the other two colonias. Notably, the response to palm oil treatment was comparable to treatment with beadlets in the Via Alemania and Los Pinos studies, where the initial concentrations were similar.

The mothers in these colonias nurse frequently and on demand, so that full breast expression is not possible. Therefore, to control for changing lipid concentrations over the nursing episode, milk concentrations were normalized to lipid. Since normalization gave comparable results, there was no significant effect of changing lipid concentrations over the nursing episode. Milk retinol and other carotenoids were not significantly affected by any of the treatments.

Infant serum retinol was significantly increased by both maternal β-carotene supplementation and red palm oil consumption. As in the case of serum and milk carotenoids, the largest increases were in response to β-carotene beadlets in the Via Cristina study. However, the increases in response to palm oil supplementation were similar to those in response to β-carotene supplementation in the Via Alemania study. The powdered β-carotene preparation was less effective than the other treatments (table 3).

The initial serum retinol concentrations of the infants ranged from 0.48 to 0.88 mmol/L. The average concentration in all studies was 0.63 mmol/L, which was less than the World Health Organization recommended value for developing countries (0.7 mmol/L). Our results are in agreement with a 1996 national survey of the Honduran Ministry of Health, which found that over 30% of all Honduran children 12 to 71 months of age had low levels of vitamin A (serum retinol between 0.35 and 0.70 mmol/L) and 10% were vitamin A deficient (serum retinol less than 0.35 mmol/L) [20, 22]. With the advent of Hurricane Mitch, unfortunately, the vitamin A status of Honduran children almost certainly has now worsened, increasing the urgency of finding a sustainable solution to the problem of vitamin A deficiency in this population.

In summary, both β-carotene supplementation of mothers and red palm oil in the maternal diet improved the vitamin A status of the mother–infant pair in Honduran colonias. Red palm oil is comparable in effectiveness to supplementation with β-carotene. Both treatments significantly increased serum and milk β-carotene and infant serum retinol. The initial vitamin A status of the infants was marginal-to-deficient, and the maternal diet was low in vitamin A. Because the local diet typically includes foods prepared with oil, the possibility that dietary red palm oil could provide a significant source of provitamin A carotenoids for Honduran women and children should be further investigated.

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References

1. Fawzi WW, Chalmers TC, Herrera MG, Mosteller F. Vitamin A supplementation and child mortality: a meta-analysis. JAMA 1993;269:898–903.
2. Humphrey JH, West K Jr, Sommer A. Vitamin A deficiency and attributable mortality among under 5-year olds. Bull WHO 1992;70:225–32.
3. Solomons NW. Plant sources of vitamin A and human nutrition: red palm oil does the job. Nutr Rev 1998; 56:309–11.
4. van Stuijvenberg ME, Kvalsvig JD, Faber M, Kruger M, Kenoyer DG, Benadé AJ. Effect of iron-, iodine-, and β-carotene-fortified biscuits on the micronutrient status of primary school children: a randomized controlled trial. Am J Clin Nutr 1999;69:497–503.
5. Manorama R, Brahmann GN, Rukmini C. Red palm oil as a source of β-carotene for combating vitamin A deficiency. Plant Foods Hum Nutr 1999;49:75–82.
6. Bulux J, Quan de Serrano J, Giuliano A, Perez E, Lopez CY, Rivera C, Solomons NW, Canfield LM. Plasma response of children to short-term chronic β-carotene supplementation. Am J Clin Nutr 1994;59:1369–75.
7. Jalal F, Nesheim MC, Zulkarnain A, Sanjur D, Habicht JP. Serum retinol concentrations in children are affected by food sources of β-carotene, fat intake and anthelmintic drug treatment. Am J Clin Nutr 1998;68:623–9.
8. Solomons NW, Bulux J. Identification and production of local carotene-rich foods to combat vitamin A malnutrition. Eur J Clin Nutr 1997;51:S39–45.
9. Canfield LM, Bulux J, Quan de Serrano J, Rivera C, Lima AF, Lopez CY, Perez R, Khan LK, Harrison GG, Solomons NW. Plasma response to oral β-carotene in Guatemalan schoolchildren. Am J Clin Nutr 1991;54:539–47.
10. Canfield LM, Giuliano A, Neilson E, Blashill B, Graver E, Yap H. Kinetics of the response of milk and serum β-carotene to daily β-carotene supplementation in healthy, lactating women. Am J Clin Nutr 1998;67:276–83.
11. Canfield LM, Giuliano AR, Neilson EM, Yap HH, Cui HA, Blashill BM. β-Carotene in breast milk and serum is increased following a single β-carotene dose. Am J Clin Nutr 1997;66:52–61.
12. Stoltzfus RJ, Hakimi M, Miller KW, Rasmussen KM, Dawiesah S, Habicht JP, Dibley MJ. High dose vitamin A supplementation of breast-feeding Indonesian mothers: effects on the vitamin A status of mother and infant. J Nutr 1993;123:666–75.
13. Choudhury N, Tan L, Truswell AS. Comparison of palmolein and olive oil: effects on plasma lipids and vitamin E in young adults. Am J Clin Nutr 1999;61:1043–51.
14. Ghafoorunissa, Reddy V, Sesikaran B. Palmolein and groundnut oil have comparable effects on blood lipids and platelet aggregation in healthy Indian subjects. Lipids 1999;30:1163–9.
15. Ghafoorunissa. Nutrition and health implications of palm oil in Indian diets. Indian J Med Res 1999;102:233–40.
16. Canfield LM, DeKaminsky R, Taren DL, Mahal Z. Maternal β-carotene supplementation: a strategy for improving the vitamin A status of the mother–infant dyad. J Nutr Biochem 1999;10:532–8.
17. Canfield LM, Kaminsky RG, Shaw EH, Sander JK. Dietary palm oil improves the vitamin A status of the mother–infant dyad. Am J Clin Nutr 1999 (in press).
18. Jackson JG, Lien EL, White SJ, Bruns NJ, Kuhlman CF. Major carotenoids in mature human milk: longitudinal and diurnal patterns. J Nutr Biochem 1998;9:2–7.
19. Lucas A, Gibbs JAH, Lyster RLJ, Baum JD. Creamatocrit: simple clinical technique for estimating fat concentration and energy value of human milk. BMJ 1978;1:1018–20.
20. Nestel P, Melara A, Rosado J, Mora JO. Vitamin A deficiency and anemia among children 12–71 months old in Honduras. Revista de Salud Publica 1999;6:34–43.
21. Papas AM. Carotenoids and human health: current issues. Xerophthalmia Club Bull 1999;70:1–2.
22. Secretaria de Salud, Tegucigalpa, Honduras. Encuesta nacional sobre micronutrientes (National Honduran micronutrient survey), 1996. Tegucigalpa: Secretaria de Salud, 1998:28–9.

Engaging communities in a sustainable dietary approach: A Thai perspective

Suttilak Smitasiri

Abstract

Lessons learned from developing countries indicate that various development attempts, including nutrition, are not sustained because of inadequate community participation. Although technologies can be introduced, their sustainability will depend almost entirely on the local population. More than a decade of experience in promoting consumption of vitamin A–rich foods in Thailand points to the understanding of contexts and trends of overall national development, strategic positioning of the change process, effective social mobilization, and importance of policy communication as being essential for engaging communities in sustainable endeavours. Information technology, current diet, and the health movement as well as future development approaches will lead to improved opportunities for a sustainable dietary approach. However, the need to reconsider the current nutrition science paradigm and the new market system remains a challenge.

Introduction

The United Nations University/International Union of Nutritional Sciences (UNU/IUNS) workshop represented an important opportunity for the international nutrition community, especially members from Asian countries, to share accumulated experiences on a dietary approach to vitamin A deficiency. This approach, if implemented well, will have a good potential to improve vitamin A status, adding to overall nutrition development and strengthening regional food and nutrition security.

The epidemiology of vitamin A deficiency may vary but has a similar overall pattern. This deficiency is most prevalent within the context of poverty, environmental deprivation, and social disparity [1]. To prevent it, sufficient intake of foods rich in "vitamin A" (preformed retinyl esters or provitamin A carotenoids) is needed to meet individual requirements [2]. In general, there are many varieties of vitamin A–rich foods available, but socio-economic factors often constrain access to the foods. Also, there are widespread and inexpensive vitamin A–rich foods in poor communities, but the populations suffering from deficiency do not make proper use of them. The Institute of Nutrition of Mahidol University (INMU) recognizes the potential of these particular foods and has strategically focused on a comprehensive promotion of such foods as a means of improving vitamin A status in north-east Thailand, a region known for its large and poor population.

Lessons learned from past development attempts, including nutrition, indicate the need for a more sustainable approach [1]. Demand is now increasing that arrangements be made to give people opportunities and resources for community action [3]. Nutrition interventions that are effective during the project or programme periods but not sustained afterward are unlikely to contribute towards genuine development. Moreover, nutrition as a development intervention is complex in nature [4]. To be successful and sustainable, a programme needs not only nutrition knowledge but also appropriate knowledge implementation for each particular context [5, 6].

At present, fortification and dietary diversification are two important strategies for a dietary approach to vitamin A deficiency. A successful vitamin A fortification programme usually relies on appropriate technology, sustained commitment of service providers (government and related industries), and continued demand for the fortified products. Although effective dietary diversification programmes often require good recommendations, the eventual outcomes should be participation, involvement, and behavioural change.

Promotion of vitamin A–rich foods in Thailand from 1987 to the present

Based on the recognition of the importance of vitamin A to nutrition and health, INMU conducted a small

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food-consumption survey in Si-Sa-Ket and Ubol Ratchatani, two provinces in the north-east [7]. Preliminary results indicated that over half of the mothers (18–35 years of age, $n = 148$) and children (2–6 years of age, $n = 156$) consumed insufficient quantities of vitamin A–rich foods to meet the recommended daily allowance (RDA) of vitamin A. Pre-school children were the most at risk, since over 80% had vitamin A intakes below the RDA. The survey also revealed a remarkably low fat intake by all groups.

From October 1988 to September 1991, INMU implemented a US Agency for International Development (USAID)-sponsored project entitled "Social Marketing of Vitamin A Rich Foods" (SM/VAF) in Kanthararom District, Si-Sa-Ket Province. Trakan Phutphol District in adjacent Ubol Ratchatani Province served as the control. This three-year dietary diversification project in north-east Thailand used nutrition education and communication as its main approach. At the end of the intervention, the results from quantitative and qualitative evaluations indicated its success in changing knowledge, attitudes, and practices with regard to vitamin A dietary behaviour [8]. Figure 1 shows that vitamin A intake among members of the intervention group increased significantly, whereas no increases were evident for the control area.

After the project, INMU disseminated the results and experiences of the study to the nutrition and health community as well as to the public via the mass media. The project received the highest publicity in the country when Her Royal Highness Princess Maha Chakri Sirindhorn visited the SM/VAF Project site on 9 April 1992. Between 1992 and 1993, INMU assisted Yang Chum Noi, a small district next to the original SM/VAF Project, in the district-initiated vitamin A promotion project. Lessons learned from this project indicated that the SM/VAF Project approach could be applied to existing infrastructure at a district level, and that primary schools are good strategic units for change. Based on this, local government administrators requested INMU to expand the promotion to five more districts. At present, INMU, the Foundation for Children, and the Toyota Thailand Foundation are working on the promotion with local governments and communities in 12 districts in the north-east, covering more than 400 schools and over one million people. The early phase of the expansion was made possible with the support of the Micronutrient Initiative, the United Nations Children's Fund, the Holt Sahathai Foundation, the Middle Foundation (Thailand), and the Phuthamonthon Artist Group. Some monitoring indicators from the current "We Love Green Vegetables" intervention are shown in figure 2.

In 1995 the Health System Research Institute in Thailand sponsored a study to examine the sustainability of the SM/VAF Project. Figure 3 shows a sustained vitamin A behavioural change among target groups in Kanthrarom District four years after the SM/VAF Project. However, it was recognized that although the SM/VAF Project was successful in changing broad community behaviour and achieving individual changes in knowledge, attitudes, and practices, sustaining behavioural change would require greater community strengthening and empowerment. Between 1996 and 1997, INMU, with the support of USAID/OMNI Research and the International Center for Research on Women, implemented an in-depth intervention in four subdistricts of Kanthrarom as a follow-up of the SM/VAF Project. Table 1 shows that community strengthening and empowerment were important to the improvement of vitamin A intake and could contribute to overall micronutrient interventions. On the basis of these accumulated experiences, INMU is preparing a manual to be distributed to communities and schools in various parts of the country.

Sustainability and dietary intervention

The sustainability of a dietary intervention rests on the

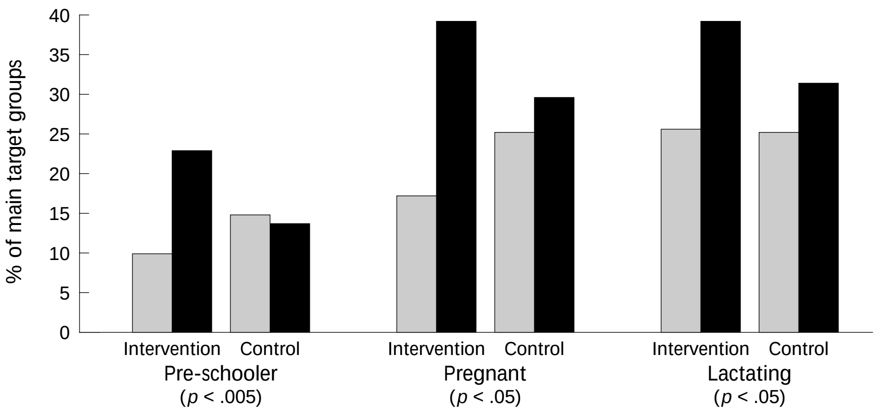

FIG. 1. Percentage of main target groups consuming vegetables containing more than 400 RE of vitamin A per 100 g daily, before (shaded bars) and after (dark bars) the SM/VAF Project

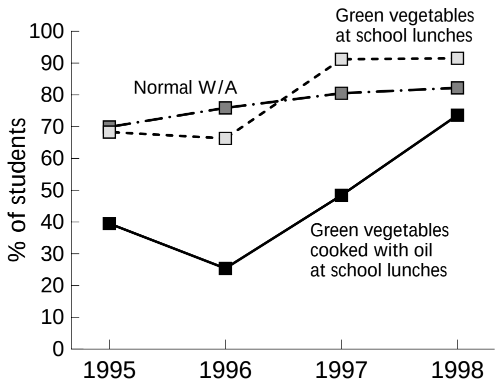

FIG. 2. Some monitoring indicators from the current "We Love Green Vegetables" intervention, 1995–1998

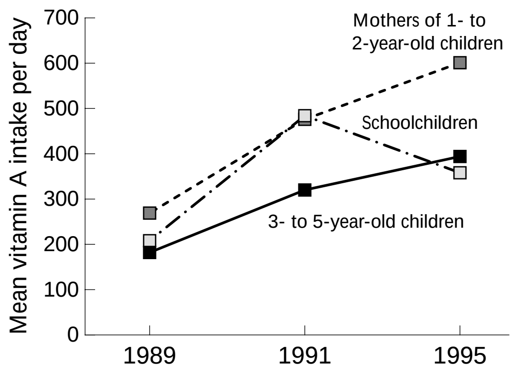

FIG. 3. Mean ± SD daily vitamin A intake (RE) of target groups in Kanthararom, before (1989) and after (1991) the SM/VAF Project and four years later (1995)

ability to keep the adopted dietary change going after the initial intervention. Reflections on the SM/VAF Project had critically implied that a successful intervention by itself, without an adequate time and transition period, would not have a high probability of sustainability [6]. Participation and empowerment are necessary [9] but are often difficult to establish [10]. It has been suggested that after an intervention has achieved a satisfactory level of success, an approach must be systematized and made part of the normal functioning of the local system [11].

INMU's continuous effort in promoting vitamin A–rich foods has been an attempt to use the SM/VAF Project as an example to sustain interests of stakeholders to maintain and improve the change. It is expected that experience from this implementation will assist others in developing more successful interventions. This should eventually lead to the development of a critical mass of people crucial in effecting sustained behavioural change in Thailand.

Essential elements of a sustainable dietary approach

INMU's promotion of vitamin A–rich foods is a district-based dietary diversification intervention aimed at increasing vitamin A supply and consumption. This approach relies mainly on two change strategies: education and social marketing. Based on a community organization framework [12], the intervention has given priority to participation and involvement of the community, its organizations, and interpersonal influences. Moreover, it adopts social cognitive theory [13], which states clearly that people themselves control all power and decision-making about whether or not to change behaviour. Change agents can only assist them to adjust to personal and environmental factors that facilitate appropriate behavioural modification, acceptance, and adherence.

These theoretical frameworks therefore led to one important assumption: the poor are key actors in a sustainable dietary improvement. This assumption has been used to guide project implementation since its beginning. As a consequence, the participation of the people is a focus of our intervention strategy. The social marketing approach is used to design, implement, and control activities calculated to engage people, especially the poor, to increase their supply and consumption of vitamin A.

Seven essential elements were identified as crucial for the success of the SM/VAF Project's implementation: (1) All involved need to recognize that the intervention's cause is of significance to them. (2) Change initiators are important for their vision and guidance. (3) Adequate resource investment and psychological support must be considered. (4) Cooperative interdisciplinary teamwork with good networking is an indispensable commodity. (5) Strategic implementation, "self

TABLE 1. Significant changes in intake of vitamin A and iron among target groups between 1996 and 1997

Nutrient	2–5 years		10–13 years		Pregnant		Lactating	
	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control
Vitamin A	↑	↑	↑	↑	↑	—	↑	↑
Iron	—	↑	↑	—	—	—	↑	↑

↑ Significant increase ($p < .05$)   — No significant change efficacy," effective decision-making processes, suitable managerial skills, and appropriate personality of the team are necessary for creative action. (6) Persons who are directly involved with the operation should have good attitudes towards the mission. (7) Characteristics of change agents should include strategic thinking, talent and creativity, technological orientation, interactive orientation and ability, good listening skills, and desire to make a difference, as well as knowledge of related issues and the nature of the target community [6].

Nevertheless, a successful intervention may not be a sustainable one. Technologies can be transferred, but the sustainability of the adoption depends almost entirely on the local people. A situational and an enduring involvement is important to maintain the adopted change [14]. According to our experiences in the past decade, four more essential elements are critical for an intervention's sustainability: understanding of contexts and trends of overall national development, strategic positioning of the change process, effective social mobilization, and the importance of policy communication.

Understanding of contexts and trends of overall national development

It has been said that many nutrition interventions in developing countries have been designed without a good assessment of local conditions and recognition of existing potential [15]. Many technology-transferred projects were successful during the project periods, but most of them did not really contribute to long-term nutritional improvement. The SM/VAF Project's intervention strategy was developed on the basis of the fact that Thailand is primarily an agrarian society, with about three-fourths of the population residing in rural areas. Furthermore, the Seventh Thailand National Economic and Social Development Plan (1987–1991) clearly indicated the policies to promote and increase the opportunity of the people to participate in development of their quality of life through effective community preparation, public information, and communication [16]. Thus, it was understood that improving vitamin A through dietary diversification should be accepted by all involved and feasible for engaging communities in the change process.

At the early stage of the intervention, promotion of homestead green vegetable production was not smooth because of the industrial and export-oriented agricultural development policy at the time. The SM/VAF Project was able to achieve its objectives because it only asked for minimum production (first for children and mothers), which could be done by children, women, or older members of the family. Moreover, the increasing awareness of pesticide danger in the country has helped activate homestead vegetable production. When the economic crisis started in early 1997, the Thai Government announced an agricultural-based, self-sufficient economy policy, and all ministries have been actively urging the communities to produce foods locally. With over a decade of experience, INMU is ready to assist. This is the reason, it is argued, that INMU's promotion of vitamin A–rich foods has a positive chance of sustainability.

Strategic positioning of the change process

Social marketing has been the approach that INMU uses to guide its vitamin A intervention. The key components of the intervention are setting measurable objectives, research on human needs, targeting products to specialized groups of consumers, the technology of positioning products to fit human needs and wants and effectively communicating their benefits, constant attention to changes in the environment, and the ability to adapt to change [17].

The SM/VAF Project used social marketing to build a solid nutrition education and communication programme and create a local demand for more vitamin A supply and consumption. The project positioned vitamin A–rich foods as something used by loving and caring mothers. Locally, the project was named the "A Mother Loves Her Child" project. The tangible product—a local vitamin A–rich dark-green vegetable, ivy gourd (*Coccinia indica*)—was used to reinforce this theme. The project had three implementation stages. The first stage, which lasted throughout the project, created and maintained information, education, and communication on nutrition and care, including vitamin A. This was followed by promotion of the ivy gourd as an image representing other vitamin A–rich vegetables. The third stage combined nutritional messages with concrete action programmes designed and carried out by the communities [18].

One common misunderstanding about the SM/VAF Project is that it was interested in promoting only one green vegetable. When questions regarding the efficacy of vegetable sources in combating vitamin A deficiency were highlighted, the approach taken was almost groundless to many. Nevertheless, INMU has maintained its intervention strategy. Since the beginning, the project was planned as a comprehensive vitamin A nutrition communication project. Green vegetables were not perceived as the best sources of vitamin A, but as the best strategic sources for possible change in northeast Thailand. It was understood that poor people in the region would have self-efficacy in local vegetable production and consumption, which would lead to improved vitamin A–rich vegetables, vitamin A intake in general, and possibly overall nutrition, if the project was implemented appropriately.

At present, it can be said that the decision on strategic positioning of the change process for the SM/VAF Project and its following interventions was a good one.

The intervention strategy has proved to be feasible for local adoption and expansion. In addition, current promotion of “grow your own foods” and increasing awareness of the importance of pesticide-free indigenous vegetables to engage the communities in the intervention approach has been encouraging. Thus, it can be concluded that food and nutrition recommendations should be examined from many aspects in order to effectively position intervention strategy. If sustainability of change is intended, the conditions for the initiation, management, and adjustment of such recommendations are important [19].

Effective social mobilization

To sustain a dietary intervention, social mobilization must be maintained after the initial intervention to ensure that the intervention approach will be integrated into the overall development in the target community [1]. The effectiveness of this process is, in general, dependent on the quality of interpersonal communication, interaction, and appropriate actions provided by all those who are working on the intervention. These activities are both labour and service intensive, but they often are not considered as real work in nutrition implementation. Personal communication is in fact embedded in virtually every facet of social mobilization [20].

Our experiences indicate that vitamin A by itself does not have enough power to mobilize the communities in general. Vitamin A, if used as a strategic nutrition issue for improving health and overall quality of life, has more potential in getting the attention of multiple intermediaries for maintaining and fostering dietary change. In Thailand nutrition has been positioned as a significant factor for education, health, agriculture, and overall socio-economic development. Therefore, it is suggested that the integration of micronutrients into overall nutrition will be helpful for social mobilization.

Poor people do not normally give high priority to nutrition and health. Nevertheless, they can be convinced that nutrition and health are important by good facilitating processes. The technology for this work is available [21], but lack of consensus on nutrition priorities, inadequate resources, and weak implementing organizations remain significant obstacles to effective social mobilization for dietary improvement in most developing countries.

Figure 4 shows a proposed conceptual framework for creating effective social mobilization for vitamin A and nutrition improvement.

The importance of policy communication

Nutrition education is traditionally used as a mechanism to educate the target populations about the dangers of poor nutrition and the benefits of good nutrition and to inform them about possible solutions [22]. This is based on the assumption that when people have adequate knowledge, they will consequently improve nutrition. Recently, however, it has been argued that not only the target populations, but also many significant persons and groups in the communities, must be involved in nutrition improvement [23]. Our experiences support this view. Policy and decision makers, government administrators, active social development organizations, mass media, and the public are all critical for a sustainable dietary intervention.

Policy communication is designed particularly to inform and educate stakeholders in the communities on the rationale for a particular policy and key implementation components. To improve, expand, and sustain a dietary intervention, policy communication should be planned and implemented in the intervention area long before the end of the intervention. This process can be initiated by including stakeholders in discussions about the progress of the intervention, its foreseeable outcomes and impacts, and future activities. Special policy communication activities should be designed by using an audience-centred approach to ensure adequate participation and involvement of important stakeholders in the communities. Mass media can be helpful in advancing the agenda.

At the end of an initial intervention, policy communication should advocate the results and share experiences with wider audiences in order to expand and sustain the change. These activities need to be carefully designed and well implemented; adequate investment is thus essential. In order to engage the local communities in a sustainable dietary intervention, the nutrition community must be willing to work as a facilitator until the change can be sustained by the local communities themselves. This requires long-term thinking and partnership in development, not a narrowly focused, nutrient-specific intervention [1].

Future opportunities and challenges

Accumulated knowledge from implementing micronutrient interventions around the world in the past two decades should help the nutrition community move forward in the twenty-first century. We expect that the progress of information technology will create more rapid changes. When the public is more informed and educated, they will understand more about the importance of diet and health. On the basis of movements already started in developed countries, consumption of local quality foods should be favourable. Subsequently, dietary improvement should receive more positive attention from stakeholders in developing countries.

Table 2 compares modern and post-modern currents in development [24]. Our experience indicates that a

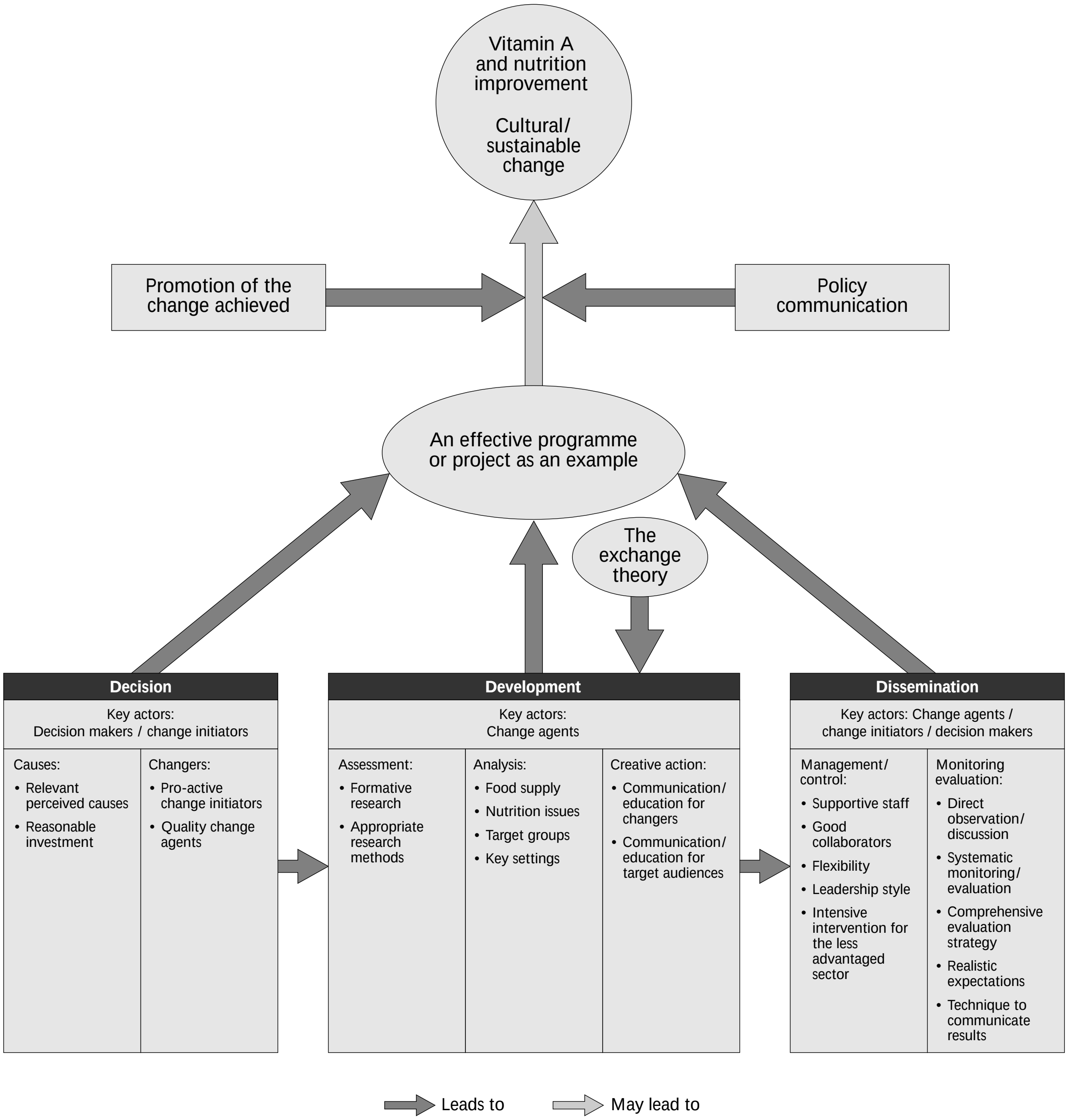

FIG. 4. Conceptual framework for creating effective social mobilization for vitamin A and nutrition improvement

micronutrient dietary approach can be used to position nutrition improvement along the post-modern development approach. Underlying reality objectives, the planning approach, and implementation must be considered in developing a sustainable dietary intervention. It is indeed the responsibility of the nutrition community to advocate, join forces, and continue the commitment to end malnutrition by 2020, as already agreed by major food and nutrition conferences in the 1990s.

With rapid changes and increasing complexity, new ways of thinking and working need to be considered. A problem-oriented and participatory approach has been proposed to replace the present discipline-based approach in order to create a closer link between knowledge and implementation of knowledge. Nutrition scientists, policy and programme planners, and implementers at all levels are urged to consider a holistic, flexible systems approach that engages the communities, as well as monitoring and adjusting the system to the dynamics of local changes [1, 5, 6, 19]. This paradigm shift remains a major challenge for the nutrition community in the coming years.

Vitamin A deficiency is fundamentally a nutritional disorder. However, a dietary solution is not straight-

TABLE 2. Modern and post-modern currents in development

Currents	Modern	Post-modern
Underlying reality objectives	Simple, uniform growth Preoccupation with macro	Complex, diverse development Preoccupation with micro
Planning approach	Plan Model Top-down Centralize	Enable Interact Bottom-up Decentralize
Implementation	Blueprint Role culture Standardization	Process Task culture Flexibility, innovation

Adapted from ref. 23.

forward [2]. Access to adequate, nutritious food is a key prerequisite for good nutrition. Dietary improvement thus involves a whole host of socio-economic and environmental complex factors. Increasingly, the new market system has been observed to have an impact on world food systems. This single and integrated market is influencing and adjusting flows of trade, finance, and information globally. Future dietary interventions must be designed on the basis of good understanding of this globalization process.

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References

1. Underwood BA, Smitasiri S. Micronutrient malnutrition: policies and programs for control and their implications. Annu Rev Nutr 1999;19:303–24.
2. Sommer A, West K. Vitamin A deficiency: health, survival, and vision. New York and Oxford: Oxford University Press, 1996.
3. Independent Task Force on Community Action for Social Development. Partnerships for social development: a casebook. Franklin, W Va, USA: Future Generations, 1995.
4. Pinstrup-Andersen P. Targeted nutrition interventions. Food Nutr Bull 1991;13:161–9.
5. Garza C, Haas JD, Habicht JP, Pelletier DL, eds. Beyond nutritional recommendations: implementing science for healthier populations. New York: Division of Nutrition Science, Cornell University, 1996.
6. Smitasiri S. Nutri-action analysis: going beyond good people and adequate resources. Nakorn Phathom, Thailand: Institute of Nutrition, Mahidol University, 1994.
7. Sommer A, Tarwotjo I, Djunaedi E, West KP Jr, Loeden AA, Tilden R, Mele L, and the Aceh Study Group. Impact of vitamin A supplementation on childhood mortality: a randomised controlled community trial. Lancet 1986;1:1169–73.
8. Smitasiri S, Attig G, Dhanamitta S. Participatory action for nutrition education: social marketing vitamin A–rich foods in Thailand. Ecol Food Nutr 1992;28:199–210.
9. Jonsson U. Community-based development—from a programme towards a movement. SCN News 1991; 7:15–22.
10. Ward GW. The national high blood pressure education program: an example of social marketing in action. In: Frederiksen LW, Solomon LJ, Brehony KA, eds. Marketing health behavior. New York: Plenum Press, 1984:93–113.
11. Pyle DF. From pilot project to operational program in India: the problems of transition. In: Grindle MS, ed. Politics and policy implementation in the third world. Princeton, NJ, USA: Princeton University Press, 1980: 123–44.
12. Rothman J. Three models of community organization practice, their mixing and phrasing. In: Cox FM, ed. Strategies of community organization. 3rd ed. Chicago, Ill, USA: F. E. Peacock, 1979:25–45.
13. Bandura A. Social foundations of thought and action: a social cognitive theory. Englewood Cliffs, NJ, USA: Prentice-Hall, 1986.
14. Rothschild ML. Marketing communications in nonbusiness situations or why it's so hard to sell brotherhood like soap. J Marketing 1979;43:11–20.
15. Jonsson U. Success factors in community-based nutrition oriented programme and projects. Presented at a International Congress of Nutrition (ICN) Follow-up Meeting, New Delhi, November 1995.
16. Kachondham Y, Attig GA. Thailand and its socio-economic and health policy development. In: Winichagoon P, Kachondham Y, Attig GA, Tontisirin K, eds. Integrating food and nutrition into development: Thailand's experiences and future visions. Nakorn Phathom, Thailand: Institute of Nutrition, Mahidol University, 1992;2:16–30.

17. Kotler P. Social marketing of health behavior. In: Frederiksen LW, Solomon LJ, Brehony KA, eds. Marketing health behavior. New York: Plenum Press, 1984:23–39.
18. Smitasiri S, Attig GA, Valyasevi A, Dhanamitta S, Tontisirin K. Social marketing vitamin A–rich foods in Thailand: a model nutrition communication for behavior change process. 2nd ed. Nakorn Phathom, Thailand: Institute of Nutrition, Mahidol University, 1993.
19. Pelletier DL. Advanced training in food and nutrition: disciplinary, interdisciplinary, and problem-oriented approaches. Food Nutr Bull 1997;18:134–45.
20. Kotler P, Roberto EL. Social marketing: strategies for changing public behavior. New York: Free Press, 1989.
21. Isreal RC, Tighe JPN. Nutrition education: state of the art: a review and analysis of the literature. Nutrition Education Series 7. Paris: UNESCO, 1984.
22. Smith B. Past experiences and needs for nutrition education: summary and conclusions of nine case studies. In: Food and Agriculture Organization of the United Nations. Nutrition education for the public: discussion papers of the FAO expert consultation. FAO Food and Nutrition Paper 62. Rome: FAO, 1997:1–36.
23. Berg A. More resources for nutrition education: strengthening the case. J Nutr Educ 1993;25:278–82.
24. Maxwell S. Food security: a post-modern perspective. Food Policy 1996;21:155–70.

Moving a health system from a medical towards a dietary approach in Thailand

Emorn Wasantwisut, Uraiporn Chittchang, and Sangsom Sinawat

Abstract

Amidst the picture of subclinical vitamin A deficiency in north and north-east Thailand, hospital records revealed 31 cases of infant xerophthalmia in the lower southern region in 1991. Major risk factors included inadequate breast-feeding, consumption of non-fortified sweetened condensed milk, and the presence of pneumonia, diarrhoea, or both. A survey conducted jointly by the Ministry of Public Health (MOPH) and the Institute of Nutrition, Mahidol University (INMU), indicated a public health problem of vitamin A deficiency in pre-school children. A partnership relationship was established between MOPH as an implementation agency and INMU in the technical support role towards alleviating vitamin A deficiency in the lower southern provinces. Intervention began with distribution of high-dose vitamin A capsules in the high-risk areas, followed by fortification of sweetened condensed milk with vitamin A (330 retinol equivalents/100 g). At the same time, a dietary diversification strategy was planned to promote consumption of vitamin A–rich foods in the local menus or fish chips enriched with chicken or beef liver. No new cases of xerophthalmia have been reported since 1995. Periodic subsample surveys indicated that the severity of the problem has declined to a subclinical stage. Key elements of progress include partnership between MOPH and INMU from planning to implementation, transition of MOPH to a more preventive and promotive approach, continuous communication from top to grass-roots-level officers, and coupling of research with programmes.

Introduction

The indication that Thailand had a vitamin A deficiency problem came from a joint Thai–United States national nutrition survey in 1960, data from which were published by the US Interdepartmental Committee on Nutrition for National Defense (ICNND) [1]. The ICNND report revealed that the intake of vitamin A was inadequate, and that vitamin A malnutrition was evident among infants and small children in the north and north-east regions. A later clinical study in Chiang Mai, northern Thailand, reported a high prevalence of xerophthalmia among patients with severe protein–energy malnutrition [2]. In Bangkok liver autopsy examinations revealed inadequate vitamin A intake among children of low-income families [3]. As a result, the Thailand Fourth National Economic and Social Development Plan (NESDP; 1977–1981) included vitamin A deficiency as one of the seven national nutritional problems.

Thailand's effort to control and prevent vitamin A deficiency in the 1970s and the 1980s was unique. Since the problem of vitamin A deficiency occurred primarily in pocket areas and its prevalence trailed behind those of protein–energy malnutrition, iron-deficiency anaemia, and iodine-deficiency disorders, national nutrition improvement programmes have not been aimed specifically at vitamin A. Rather, the programmes have focused on the alleviation of all severe malnutrition problems and have included vitamin A under their umbrella. Vitamin A considerations were integrated into Thailand's health and nutrition policies, plans, and programmes along with other nutritional problems. During the Fourth NESDP (1977–1981), the approaches taken by government health sectors centred on the creation of strong awareness at all public and private levels and targeted treatment through health services of those with xerophthalmia, severe protein–energy malnutrition, or both, in addition to general nutrition education.

Under the Fifth NESDP (1982–1986), nutrition programmes became a part of the Poverty Alleviation Plan, which linked together the activities of four major ministries (Health, Agriculture, Education, and Interior) in order to improve the quality of life of poor villagers. The strategies employed to improve the nutritional status of the target population included programmes

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such as growth monitoring, nutrition education, horticulture projects to produce nutritious foods in the community, supplementary feeding programmes, school lunch programmes, and food fortification, emphasizing iodization of salt [4]. These multisectoral activities, along with support from research and training programmes, paved the way for alleviating the severity of major nutrition problems, including vitamin A deficiency. By the end of the Fifth NESDP, case reports of xerophthalmia became rare, and the country began to encounter a transition in the vitamin A deficiency problem from severe to marginal or subclinical levels [5]. Therefore, in 1985 the World Health Organization (WHO) classified Thailand as a country where vitamin A deficiency was not a public health problem, although sporadic cases might occur [6].

Although severe vitamin A deficiency has declined in most regions, several surveys of limited scope revealed a high prevalence of subclinical vitamin A deficiency in different rural areas of Thailand, as evidenced by low vitamin A intake [5] and low serum retinol concentrations among pre-school children [7] and schoolchildren [8] of north-east Thailand. A 1990 survey in northern and north-eastern Thailand indicated that approximately one-fifth of pre-school children had subclinical vitamin A deficiency, as evidenced by low liver stores (relative dose–response test) and abnormal conjunctival epithelium [9]. Since the north and north-east regions of Thailand are facing the problem at a marginal or subclinical level, an intervention programme to promote consumption of vitamin A–rich foods is most appropriate. However, although vitamin A–rich foods, such as yellow and orange fruits and vegetables, dark-green leafy vegetables, liver, eggs, and whole milk, are readily available in most areas in Thailand, they are underutilized due to such factors as consumption behaviour, seasonal variation, and food appeal. Recent experience in social marketing of the ivy gourd plant (*Coccinia indica*), which is rich in provitamin A carotenoids, in north-east Thailand demonstrated that significant changes in dietary habits can be achieved in a relatively short time [10, 11]. A follow-up study of the social marketing project indicated a sustained improvement in the consumption of vitamin A–rich foods and fat, leading to a significant increase in serum retinol concentrations of pre-school children in the intervention group compared with those of the control group [12]. Another factor concerning the effect of local food preparation and preservation techniques on the loss of vitamin A activity was addressed through multicountry efforts, as reported elsewhere [13].

Xerophthalmia in lower southern Thailand

Whereas the problem in the north and north-east regions appears to be marginal, a hospital-based record in Yala Province of southern Thailand during 1988 to 1991 revealed alarming evidence of 31 cases of xerophthalmia among 3- to 15-month-old infants [14]. Most of the infants belonged to families of migratory rubber plantation workers. The causes included little or no breastfeeding, consumption of non-fortified sweetened condensed milk, diarrhoea and pneumonia, partial or incomplete immunization, poverty, and maternal illiteracy. A 1992 vitamin A survey in five provinces of the lower southern region revealed that 0.43% of two- to six-year-old children had keratomalacia, 10.5% had low serum retinol concentrations (<0.70 μmol/L), and 56% had inadequate liver stores (according to the modified relative dose–response test)[15].

A partnership was established between the officers of the Nutrition Division, Department of Health, Ministry of Public Health (MOPH), who are implementers, and the research team at the Institute of Nutrition, Mahidol University (INMU), who later played a technical support role. The goal of this partnership was to eradicate severe vitamin A deficiency in the lower southern region. The partners assessed the situation and planned the strategies to counteract the problem together. It was apparent in the beginning that the presence of active xerophthalmia called for a universal distribution of high-dose vitamin A capsules every six months to infants and pre-school children residing in the endemic areas (the capsules were supplied by Task Force Sight and Life, Basel, Switzerland, and the Royal Thai Government). This supplementation programme covered the period from 1992 to 1998. Traditional birth attendants were trained to give these supplements. In addition, the MOPH strengthened supportive measures such as maternal and child care, improved immunization coverage, and control of infection by working closely with the regional and local health officers. These combined efforts resulted in no new reported cases of xerophthalmia [16].

Moving from a medical towards a dietary approach

Both the MOPH and the INMU teams realized from the beginning that the universal supplementation programme was meant to curb the severity of vitamin A deficiency and to keep the problem under control until other measures were ready. The supplementation would ultimately be targeted to persons at high risk as a part of the health-care system. Since the perspectives of the MOPH team at that time were shifting towards a more sustainable intervention for disease prevention and health promotion, the partners discussed and planned a food-based approach for the prevention of vitamin A deficiency.

Consumption of non-fortified sweetened condensed milk was a common practice and an important risk factor for infants in the endemic area, particularly among families of migratory rubber plantation workers. Although the local health officers had difficulties in locating these target groups to advise them on appropriate child-care and feeding practices, non-fortified sweetened condensed milk was readily accessible to them and was attractive because of its low cost and convenience. Therefore, a considerable proportion of young children could still be at risk of vitamin A deficiency. To effectively curb the problem, the MOPH and INMU research teams compiled the available evidence to present a case for vitamin A fortification of all brands of sweetened condensed milk. The major thrust behind this movement was the indication that xerophthalmia involving the cornea occurred when the mothers or guardians changed from a fortified to a non-fortified brand of milk because of the lower cost of the latter. The rationale for fortification of sweetened condensed milk was to prevent any child from becoming blind as a result of being fed this food because of lack of knowledge. A meeting to discuss the matter with the manufacturers of sweetened condensed milk in Thailand resulted in full cooperation from all parties. In 1993, the Committee under the Food and Drug Administration passed an MOPH regulation that sweetened condensed milk must be fortified with vitamin A at a dose of 330 retinol equivalents (RE) per 100 g.

At the same time, the INMU and MOPH teams also planned a dietary diversification programme to promote consumption of local vitamin A–rich foods. Because the lower southern provinces are inhabited by a Thai Muslim population who have different religious beliefs and food consumption patterns, research was considered an integral component of the programme. The INMU conducted the research in collaboration with the MOPH team and local health officers. Funding was obtained by the MOPH. Formative research was first conducted to obtain background information on potential sources, availability, and consumption patterns of indigenous vitamin A–rich foods. The food-based research thereafter emphasized two activities: recommendation of vitamin A recipes for consumption by pregnant women and development of vitamin A–rich snacks (local fish chips enriched with chicken or beef liver). The outcomes of both research components have been adopted and successfully promoted by the Heath Promotion Center (Region 12) in southern Thailand as part of a special public event (Vitamin A Day), regular counselling and education programmes, and as micro-level income-generation projects by community women's groups. Details of these activities have been described elsewhere [17].

Reassessment of the situation

In 1995 the MOPH, with the technical support of the INMU, conducted a small-scale survey of vitamin A deficiency in pre-school children in the lower southern region [18]. The survey site was similar to those covered by the 1992 survey. A total of 393 children aged two to six years were examined. There were no new cases of xerophthalmia. Low serum retinol concentrations (< 0.70 μmol/L) were detected in 6.6% of the children, as compared with 10.5% in the 1992 survey. In addition, inadequate liver stores, according to the modified relative dose–response test, were found in 13%, compared with 56% in 1992. In general, it appeared that there was a transition of vitamin A deficiency from a clinical to a subclinical stage. A follow-up survey of the situation is tentatively planned in another five-year period.

Key elements and conclusion

Looking back over the progress in combating vitamin A deficiency in lower southern Thailand, we can see several elements contributing to the success. First, the partnership between the MOPH and the INMU was established from the planning phase and continued throughout the implementation. The combined efforts of the partners were aimed towards a common goal of eradication of severe vitamin A deficiency. The tragedy of several blind infants and xerophthalmic children moved the two partners to resolve their differences and work side by side to tackle the problem together. The second element that benefited the relationship was the shifting of the MOPH's attitude from a curative approach towards one of disease prevention and health promotion, leading to their adoption of and cooperation in the food-based strategy. The third element involved continuous communication from top-level planners to grass-roots-level officers throughout the programme. This motivated the local health officers to work closely with the community, and in return they obtained the community's participation and cooperation. The fourth element has to do with the fact that research was recognized as part of the intervention and not separate from it. The MOPH obtained the funding for the research carried out by the INMU team, in addition to joining the research team themselves. Therefore, the research outcome was utilized to implement the programme activities accordingly.

The partnership between the MOPH and the INMU continues. There are future tasks and new challenges ahead on the problem of vitamin A deficiency from the eruption of xerophthalmia in young children of certain hill-tribe communities in northern Thailand, moderate subclinical vitamin A deficiency in the country, the setting up of a surveillance system, and the need to evaluate the ongoing intervention programmes. Building on the lessons learned and the key elements identified in the experience of combating vitamin A deficiency in lower southern Thailand should be a strong base for a promising future.

References

1. US Interdepartmental Committee on Nutrition for National Defense. Kingdom of Thailand nutrition survey October–December, 1960. Washington, DC: Department of Defense, 1962.
2. Smith FR, Suskind R, Thanangkul O, Leitzmann C, Goodman DS, Olson RE. Plasma vitamin A, retinol-binding protein and prealbumin concentration in protein and calorie malnutrition. III. Response to varying dietary treatments. Am J Clin Nutr 1975;28:732–8.
3. Suthutvoravoot S, Olson JA. Plasma and liver concentrations of vitamin A in a normal population of urban Thai. Am J Clin Nutr 1975;27:883–91.
4. Tontisirin K, Kachondham K, Winichagoon P. Trends in the development of Thailand's nutrition and health plans and programs. Asia Pacific J Clin Nutr 1992;4:100–7.
5. Dhanamitta S, Viriyapanich T, Kachonpadunkitti Y. Vitamin A deficiency in Thailand. In: Yasumoto K, Itokawa I, Koichi H, Sanno Y, eds. Proceedings of the Fifth Asian Congress of Nutrition, Osaka, Japan. Tokyo: Center for Academic Publications, 1988:198–201.
6. World Health Organization. Prevention and control of vitamin A deficiency, xerophthalmia and nutritional blindness: summary of a proposal for a ten-year programme of support to countries. Geneva: WHO, 1985.
7. Bloem MW, Wedel M, Egger RJ, Speek AJ, Chuslip K, Saowakontha S, Schreurs WH. The prevalence study of vitamin A deficiency and xerophthalmia in northern Thailand. Am J Epidemiol 1989;129:1095–103.
8. Udomkesmalee E, Dhanamitta S, Yhoung-aree J, Rojroongwasinkul N, Smith JC Jr. Biochemical evidence suggestive of suboptimal zinc and vitamin A status in school children in northeast Thailand. Am J Clin Nutr 1990;52:564–7.
9. Nutrition Division. Report on the prevalence of inadequate vitamin A nutriture in preschool children of north and northeast Thailand. Bangkok, Thailand: Ministry of Public Health and Institute of Nutrition at Mahidol University, 1991.
10. Smitasiri S, Attig GA, Dhanamitta S. Participatory action for nutrition education: social marketing vitamin A–rich foods in northeast Thailand. Ecol Food Nutr 1992;28:199–210.
11. Attig GA, Smitasiri S, Ittikom K, Dhanamitta S. Promoting home gardening for controlling vitamin A deficiency in northeast Thailand. Food Nutr Agric 1993; 7:18–25.
12. Smitasiri S, Sa-ngobwarchar K, Kongpunya P, Subsuwan C, Banjong O, Chitchumroonechokchai C, Rusami-Sopaporn W, Veeravong S, Dhanamitta S. Sustaining behavioural change to enhance micronutrient status through community- and urban-based intervention in north-east Thailand: vitamin A. Food Nutr Bull 1999;20:243–51.
13. Wasantwisut E, Attig GA. Empowering vitamin A foods. A food-based process for Asia and the Pacific Region. Salaya, Thailand: Mahidol University, Institute of Nutrition, and Bangkok, Thailand: Food and Agriculture Organization Regional Office for Asia and the Pacific, 1995:69–89.
14. Poolpinyo T. Xerophthalmia in pediatric patients of Yala Hospital. 12th Region Med J 1992;3:19–20.
15. Nutrition Division. Vitamin A deficiency among preschool children in five southernmost provinces of Thailand. Bangkok, Thailand: Ministry of Public Health, 1995.
16. Thainuea V, Wasantwisut E, Attig GA. Thailand's battle against nutritional blindness. World Health 1995;5:27.
17. Chittchang U, Jittinandana S, Sungpuag P, Chavasit V, Wasantwisut E. Recommending vitamin A–rich foods in southern Thailand. Food Nutr Bull 1999;20:238–42.
18. Nutrition Division. Formative evaluation of vitamin A deficiency control among preschool children in five provinces of the southernmost Thailand. Bangkok, Thailand: Ministry of Public Health, 1997.

Protection of vitamin A status in Chinese children by a dietary intervention with vegetables

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Abstract

A study of seasonal fluctuation of serum vitamin A concentrations in children in northern China showed that the prevalence of low serum levels of vitamin A was due to seasonal changes in the intakes of carotenoids. To determine whether plant carotenoids could sustain or improve children's vitamin A status during the fall and winter seasons, we performed an intervention with vegetables starting in the fall in Shandong, China. At a kindergarten, the serum vitamin A concentration was less than 1.05 μmol/L in 39% of the children. For five days per week for 10 weeks, 22 children were each provided with approximately 238 g/day of green and yellow vegetables and 34 g/day of light-coloured vegetables. Nineteen children maintained their customary dietary intake in the fall season, which included 56 g/day of green and yellow vegetables and 224 g/day of light-coloured vegetables. Vitamins A-d_8 *and A-*d_4 *were given before and after the interventions, respectively, and their enrichments in the circulation were determined by gas chromatography/mass spectrometry to investigate vitamin A body stores. The serum concentration of β-carotene improved in the group fed mainly green and yellow vegetables but decreased in the group fed mainly light-coloured vegetables. The serum concentration of retinol was sustained in the group fed mainly green and yellow vegetables but decreased in the group fed mainly light-coloured vegetables (*$p < .01$*). The isotope dilution tests confirmed that total body stores of vitamin A were sustained in the group fed mainly green and yellow vegetables but decreased by 27 μmol (7,700 μg), on average, per child in the group fed mainly light-coloured vegetables (*$p < .06$*). Dietary green and yellow vegetables can provide adequate vitamin A nutrition to kindergarten children and protect them from becoming vitamin A deficient during seasons when the provitamin A food source is limited.*

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Introduction

For a vast portion of the world's population, provitamin A carotenoids from plants serve as the major dietary source of vitamin A. In China plant provitamin A carotenoids account for about 70% of dietary vitamin A [1, 2]. However, as in many developing countries, seasonal variations in the availability of plant foods result in fluctuations in intake, and thus vitamin A status declines during the fall and winter seasons. To characterize the range in distributions of serum retinol concentrations and to determine the relative effect of plant carotenoids on vitamin A nutrition, we conducted a study among 80 10-year-old Banqiao elementary schoolchildren of northern China. In the spring (April), the average serum concentration of retinol was 30 μg/dl, but over 60% of the children had serum concentrations of retinol under 30 μg/dl. However, in the fall (October), the average serum concentration of retinol was 35 μg/dl, and only 24% of the children had serum retinol concentrations under 30 μg/dl (fig. 1). The daily intakes of fat and total energy (2,000 kcal), protein (50 g), and preformed vitamin A (140 μg, from animal foods) in April and October were similar. However,the average provitamin A carotenoid intakes were higher in October (2,300 μg/day) than in April (1,400 μg/day). The prevalence of low serum retinol concentration in the spring was probably due to the low intake of carotenoids.

Vegetable intervention study

To further investigate whether ingestion of plant carotenoids can prevent or reverse decrements in vitamin A nutrition that occur during the winter, we conducted

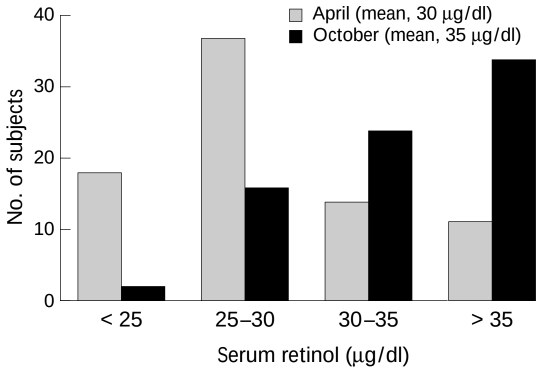

FIG. 1. Fractional distribution of serum retinol concentration of Banqiao elementary school children ($n = 80$, 10 years of age) in April (spring) and October (fall)

a 10-week vegetable intervention study during which we provided green and yellow vegetables or light-coloured vegetables and monitored their effects on vitamin A nutrition of Chinese pre-school children.

The study was conducted in Tai-An, Shan-Dong Province, 600 km south of Beijing. The availability of fruits and vegetables in Tai-An fluctuates with the season, In the fall light-coloured vegetables such as cabbage, Chinese cabbage, potatoes, and turnips are most abundant and least expensive, whereas in the summer there is a wide variety of dark-coloured vegetables and fruits.

Subjects and methods

Subjects

Two classes of 41 pre-school children (5 to 6.5 years old) whose body weights and heights were in the normal range for age were recruited into the study. Forty percent of the children had serum retinol concentrations less than 30 µg/dl. One month before the beginning of the intervention, all the children were given 400 mg of albendazole. Thus, no parasitic infection was observed in any of the children at the start of the vegetable intervention.

Methods

Retinyl acetate labelled with four or eight deuterium atoms in the molecule was used to measure the whole-body stores of vitamin A quantitatively before and after the vegetable intervention [3–7]. On day 0, 3 mg of octadeuterated retinyl acetate in corn oil was given to each child, and blood was sampled on day 3 ($n = 23$, 3-day subgroup) or day 21 ($n = 18$, 21-day subgroup) after the dose. The same procedure was repeated after the vegetable intervention using tetradeuterated retinyl acetate. The total carotenoid content of the vegetables provided during the study was determined by paper chromatographic analysis [8]. Individual carotenoids in the vegetable foods were measured by high-performance liquid chromatography (HPLC) [9].

Dietary intervention

The dietary intervention took place during days 22 to 92 of the study. The two groups of children ate their meals at school five days per week in their separate classrooms so that there was no possibility of crossover between dietary interventions. The dietary intakes of energy, fat, protein, preformed vitamin A, and minerals for the two groups during the study were similar. Both groups consumed about 30% of energy as fat, which is comparable to typical dietary intakes of children in the region. Each child in the group given mainly green and yellow vegetables ate 238 g/day of dark-green leafy or yellow vegetables, such as spinach, Chinese chive, broccoli, carrots (fresh and dried), and red yam, and 34 g/day of light-coloured vegetables, such as cabbage, Chinese cabbage, potato, cucumber, and turnip. Each child in the group given mainly light-coloured vegetables consumed 56 g/day of dark-green leafy or yellow vegetables and 224 g/day of light-coloured vegetables.

Results

The 238 g of green and yellow vegetables contained 8,280 µg of carotenoids, as determined by the paper chromatographic method [8], including 4,670 µg of β-carotene, 4,200 µg of lutein, and other provitamin A carotenoids (700 µg of α-carotene, 60 µg of cryptoxanthin, and 50 µg of 13-*cis*-β-carotene) as determined by HPLC [9]. In the 56 g of fresh green and yellow vegetables, the total carotenoid content was 1,340 µg (by paper chromatography), including 700 µg of β-carotene, 600 µg of lutein, and a negligible amount of other carotenoids (by HPLC). In the 224 g of light-coloured vegetables, the total carotenoid content was negligible (less than 10 µg). The recommended dietary allowance of vitamin A for this age group in China is 750 retinol equivalents (RE)/day [10, 11].

Serum samples were analysed by HPLC and showed that the serum concentration of β-carotene (for the three-day subgroup) was increased in the group fed mainly green and yellow vegetables and decreased in the group fed mainly light-coloured vegetables (fig. 2). The serum concentration of retinol was significantly decreased in the group fed mainly light-coloured vegetables, even though the baseline serum retinol concentration was higher in this group than in the group fed mainly green and yellow vegetables (fig. 3). Because more than 90% of total body vitamin A is stored in the liver, the measurement of serum retinol concentration does not tell us the total body stores of vita-

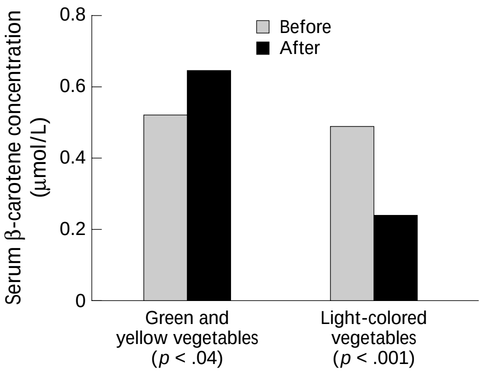

FIG. 2. Serum β-carotene concentrations of pre-school children in Tai-An measured before and after intervention with green and yellow vegetables ($n = 12$) or light-coloured vegetables ($n = 11$)

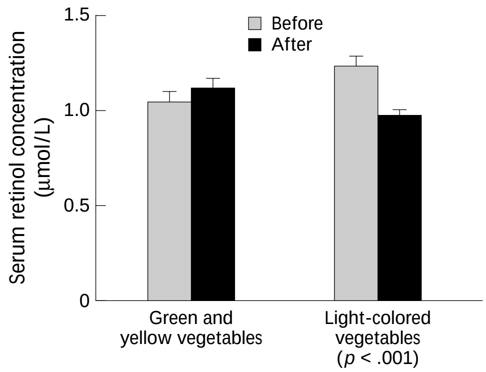

FIG. 3. Serum retinol concentrations of pre-school children in Tai-An measured before and after intervention with green and yellow vegetables ($n = 22$) or light-coloured vegetables ($n = 19$)

min A. The stable isotope technique is the only method of quantitatively measuring total body vitamin A stores, and it is minimally invasive compared with liver biopsy. We used the modified Bausch and Rietz equation and the enrichment data [12] for the serum samples collected 21 days after a labelled vitamin A dose (21-day subgroup) to quantitatively estimate total body stores of retinol before and after the intervention (fig. 4).

The total body stores of retinol of the group fed mainly green or yellow vegetables did not change, whereas that of the group fed mainly light-coloured vegetables tended to decrease ($p < .06$, paired *t* test). The average decrease was 7.7 mg per child.

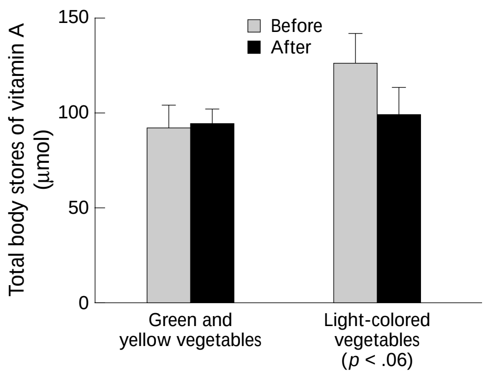

FIG. 4. Total body stores of retinol estimated by modified Bausch-Rietz equation and enrichment at 21 days after the deuterated vitamin A dose for children receiving intervention with green and yellow vegetables ($n = 10$) or light-coloured vegetables ($n = 8$)

Discussion

Comparison of intakes of carotenoids in the children's diets during the 10 weeks of intervention and the resulting total body retinol stores revealed that the additional 186.6 mg of all-*trans*-β-carotene and 38 mg of other provitamin A carotenoids (α-carotene, cryptoxanthin, and 13-*cis*-β-carotene) eaten by the group fed mainly green and yellow vegetables prevented a loss of 7.7 mg of retinol in each child's body stores. Assuming that α-carotene, cryptoxanthin, and 13-*cis*-β-carotene have half the vitamin A activity of all-*trans*-β-carotene, provitamin A carotenoids (mainly β-carotene) from the vegetables provided, we estimated the retinol equivalence to be 27 to 1 by weight or a molar ratio of 14 to 1.

Fifty grams of spinach contains 1,500 μg of provitamin A carotenoids, 50 g of carrots contains about 2,000 μg of provitamin A carotenoids, and 100 g of eggs (about two eggs) contains about 200 μg of retinol (fig. 5). Based on our conversion factor that 27 μg of provitamin A carotenoids will provide 1 μg of liver retinol, we determined that 50 g of spinach will provide 55 RE, 50 g of carrots will provide 75 RE, and 100 g of eggs will provide 100 RE. Therefore, green and yellow vegetables

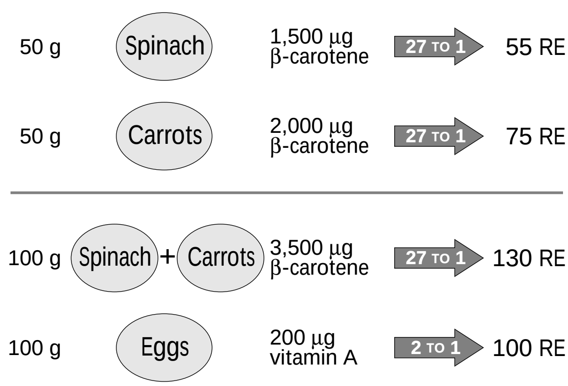

FIG. 5. Comparison between spinach, carrots, and eggs. Fifty grams of spinach will provide 55 RE, 50 g of carrots will provide 75 RE (according to our conversion factor: 27 μg of vegetable provitamin A carotenoids will provide 1 μg of retinol stored in the body), and 100 g of eggs will provide 100 RE (assuming 2 μg of preformed vitamin A will provide 1 μg of retinol stored in the body)

are equivalent to eggs in providing vitamin A nutrition.

Vitamin A nutrition in the kindergarten children during the fall months was sustained by supplying green and yellow vegetables with the meals served at the school. In the group not eating vegetables rich in carotenoids (similar to vegetable intake in the winter of northern China), the concentration of vitamin A in serum as well as in liver decreased.

Conclusions

This study demonstrated the effectiveness of vegetables rich in provitamin A carotenoids for providing adequate vitamin A nutrition to children. In areas where the availability of green and yellow vegetables is seasonal, educational programmes should be introduced to encourage a high consumption of plants containing provitamin A carotenoids.

Acknowledgements

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References

1. Ge KY, Zhai FY, Yan HC, Cheng L, Wang Q, Jia FM. The dietary and nutritional status of Chinese populations in 1990s. Acta Nutr Sinica 1995;17:123–34.
2. Ge KY, ed. The dietary and nutritional status of Chinese population (1992 National Nutrition Survey). Vol. 1. Beijing: People's Medical Publishing House, 1996.
3. Rietz P, Vuilleumier JP, Weber F, Wiss O. Determination of the vitamin A body pool of rats by an isotope dilution method. Experientia 1973;29:168–70.
4. Rietz P, Wiss O, Weber F. Metabolism of vitamin A and the determination of vitamin A status. Vitam Horm 1974;32:237–49.
5. Bausch J, Rietz P. Method for the assessment of vitamin A liver stores. Acta Vitam Enzymol 1977;31:99–112.
6. Furr HC, Amedee-Manesme O, Bergen HR, Anderson DP, Olson JA. Vitamin A concentrations in liver determined by isotope dilution assay with tetradeuterated vitamin A and by biopsy in generally healthy adult humans. Am J Clin Nutr 1989;49:713–6.
7. Haskell MJ, Handelman GJ, Peerson JM, Jones AD, Rabbi MA, Awal MA, Wahed MA, Mahalanbis, Brown K. Assessment of vitamin A status by the deuterated-retinol dilution technique and comparison with hepatic vitamin A concentration in Bangladeshi surgical patients. Am J Clin Nutr 1997;66:67–74.
8. Institution of Nutrition and Food Hygiene. Chinese food composition tables. Beijing: People's Medical Publishing House, 1991.
9. Yeum KJ, Booth SL, Sadowski JA, Liu C, Tang G, Krinsky NI, Russell RM. Human plasma carotenoid response to the ingestion of controlled diets high in fruits and vegetables. Am J Clin Nutr 1996;64:594–602.
10. Chinese Nutrition Society. Recommended dietary nutrients allowance. Acta Nutr Sinica 1989;11:93–6.
11. Chinese Nutrition Society. Illustration of recommended dietary nutrients allowance of the Chinese. Acta Nutr Sinica 1990;12:1–9.
12. Tang G, Qin J, Dolnikowski GG. Deuterium enrichment of retinol in humans determined by gas chromatography electron capture negative chemical ionization mass spectrometry. J Nutr Biochem 1998;9:408–14.

Increasing the production and consumption of vitamin A–rich fruits and vegetables: Lessons learned in taking the Bangladesh homestead gardening programme to a national scale

Aminuzzaman Talukder, Lynnda Kiess, Nasreen Huq, Saskia de Pee, Ian Darnton-Hill, and Martin W. Bloem

Abstract

Micronutrient malnutrition affects more than 20 million children and women (at least 50% of this population) in Bangladesh. The diets of more than 85% of women and children in Bangladesh are inadequate in essential micronutrients such as vitamin A, largely because adequate amounts of foods containing these micronutrients are not available, or the household purchasing power for these foods is inadequate. In Bangladesh and many other developing countries, large-scale programmes are needed to make a significant impact on this overwhelming malnutrition problem. There has been limited experience and success in expanding small-scale pilot programmes into large-scale, community-based programmes. This paper describes the development and expansion of the Bangladesh homestead gardening programme, which has successfully increased the availability and consumption of vitamin A–rich foods. The programme, implemented by Helen Keller International through partnerships with local non-governmental organizations, encourages improvements in existing gardening practices, such as promotion of year-round gardening and increased varieties of fruits and vegetables. We present our experience with the targeted programme beneficiaries, but we have observed that neighbouring households also benefit from the programme. Although this spillover effect amplifies the benefit, it also makes an evaluation of the impact more difficult. The lessons learned during the development and expansion of this community-based programme are presented. There is a need for an innovative pilot programme, strong collaborative partnerships with local organizations, and continuous monitoring and evaluation of programme experiences. The expansion has occurred with a high degree of flexibility in programme implementation, which has helped to ensure the long-term sustainability of the programme. In addition to highlighting the success of this programme, useful insights about how to develop and scale up other food-based programmes as well as programmes in other development sectors are provided.

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Introduction

Micronutrient malnutrition in Bangladesh

Micronutrient malnutrition is a serious public health problem in Bangladesh. Data from a recent national survey show that vitamin A and iron deficiencies affect more than 50% of children and women of reproductive age in rural Bangladesh [1]. Micronutrient deficiency can retard child growth, increase the duration and severity of illness, reduce work output, and slow social and cognitive development [2]. Micronutrient malnutrition among women of reproductive age increases the risk of mortality during labour and delivery and increases the risk of dietary deficiency in their newborn children during critical growth and development periods [3].

Several strategies are currently being implemented in Bangladesh to control micronutrient deficiencies with the support of the government [4]. The vitamin A capsule programme has been instrumental in achieving a decline in clinical vitamin A deficiency among pre-school children [5]. However, the target group for megadose vitamin A supplementation is limited to pre-school-age children, and there is evidence that vitamin A deficiency affects other sub-sectors of the population, including women, adolescents, and school-age children. A national blindness survey in 1982–1983 first determined that children living in households with a homestead garden were less likely to be night-blind than were children living in households without a homestead garden [6]. This finding was the basis for the development of the Bangladesh homestead gardening programme, and over the past 10 years there has been an increase in the number of organizations implementing gardening and other food-based programmes in Bangladesh.

Role of home gardening in improving micronutrient status

Despite the evidence that animal foods are the best sources of micronutrients, vegetables and fruits are often the only reliable source of micronutrients in the family diet for poor households. The production of fruits and vegetables provides the household with direct access to important nutrients that may not be readily available or within their economic reach. Therefore, home gardening is a means to improve household food security. Moreover, home gardening increases the diversity of foods available to the household, which, in turn, leads to better bioavailability and utilization of nutrients. Vegetables and fruits can also make other foods more palatable, leading to an overall increase in food intake. In their aim to improve the overall quality of the diet, home gardens address multiple nutritional requirements simultaneously. Equally importantly, home gardening has been shown to be a source of additional income for the household, since the family can sell a portion of the garden's produce. Regular programme monitoring suggests that this additional income is generally used to purchase supplementary food, further increasing the diversification of the family's diet [7]. When homestead gardening is practiced throughout the year, it can help households overcome seasonal availability of foods and promote household self-sufficiency. Although the main aim of homestead gardening programmes is to increase the production and consumption of vitamin A–rich foods, such programmes strengthen community development, support social development and empowerment of women, and improve economic growth.

Gardening practices in Bangladesh

Home gardening is an ancient method of food production that is commonly practised throughout the world [8]. Growing vegetables in the homestead is a traditional practice in Bangladesh, yet gardens often vary in size, biodiversity, and seasonal produce and are adapted to local resources and cultural preferences. Gardens are traditionally on the rooftop, or vegetables are grown scattered in the courtyard. These traditional gardens do not employ improved technology, grow only a limited number of vegetable and fruit varieties, and are generally maintained only during the cool season, which lasts three to four months.

Despite the common practice of gardening in Bangladesh, average vegetable consumption is well below the estimated requirement of 200 g per capita per day [9]. The consumption of fruits is even lower and is highly seasonal in rural Bangladesh. Furthermore, oil consumption, a requirement for adequate absorption of the β-carotene, is also well below the recommended levels [1].

In Bangladesh and many other developing countries, large-scale efforts and programmes are needed in order to make a significant impact on the overwhelming micronutrient malnutrition problem. Yet there remains limited experience and success in moving from small-scale pilot programmes to large-scale programmes, and there are only a few opportunities to share experiences across countries and across development sectors. Following an iterative process of implementation, evaluation, and planning, the Bangladesh homestead gardening programme has been successfully expanded from a pilot programme to a national programme that, in collaboration with more than 40 non-governmental organizations (NGOs), presently reaches more than 700,000 households.

Development of a homestead gardening programme in Bangladesh

Initial pilot programme

In order to explore existing gardening practices, in 1988 Helen Keller International conducted a small assessment study in north-west Bangladesh. Following this study, Helen Keller International initiated a pilot programme in 1990 among 1,000 households to explore the feasibility of promoting low-cost vegetable gardens combined with nutrition education and to identify constraints that might prevent increased production and consumption of vitamin A–rich foods among poor households.

Findings from the pilot programme suggested that with technical assistance and support, households could be encouraged to produce fruits and vegetables in the cool, rainy, and hot seasons in Bangladesh, so that production would be possible throughout the year. A mid-term evaluation in 1992 confirmed that the combined home gardening, nutrition education, and gender aspects of the programme had a very positive impact on vegetable consumption among women and young children [10]. Other findings suggested that increasing the varieties of vegetables in the garden was associated with increased vegetable and fruit intake [11].

Constraints encountered during the pilot study

A number of programme constraints were discovered during the pilot study through a continuous monitoring and evaluation system. First, households needed a regular supply of quality seed and other inputs, without which they were unable to sustain a change in gardening practices. In addition, Helen Keller International and counterparts identified other constraints to gardening, such as poor soil fertility, inadequate fencing, poor irrigation, and other practical aspects of gardening. Cultural beliefs about child feeding, food intake during pregnancy, and intra-household food distribution that might hinder optimal benefits of the programme were also identified during the pilot programme. The crucial role women play in the programme activities was also identified during the pilot programme. Finally, in addition to the agricultural and nutrition-related issues that would be addressed in the development of a larger-scale home gardening programme, the pilot team identified the need for adequate management and human resources to implement a large-scale community programme to increase the consumption of vitamin A–rich foods.

At various stages during the implementation of the study and during the planning phase that followed the evaluation, the beneficiaries and the local NGOs working in the pilot study area helped to identify and test practical solutions to these constraints. During the same time period, Helen Keller International–Bangladesh reviewed ongoing gardening programmes in Bangladesh to learn from the experience of others. This comprehensive evaluation and planning exercise was the basis of the development of the Bangladesh homestead gardening and nutrition education programme.

Linking gardening to ongoing development activities

In 1993 Helen Keller International began a national expansion of the pilot study, working in collaboration with local NGOs and the Government of Bangladesh. The objectives of the Bangladesh homestead gardening programme are to increase the number of households that sustainably produce dark-green leafy vegetables and fruits throughout the year, to increase the number of households producing more varieties of vegetables, and to increase consumption of vitamin A–rich food by the most vulnerable groups. Helen Keller International elected to implement the programme in partnership with local NGOs for a number of reasons. Malnutrition in Bangladesh results from multiple factors, including poor food intake, childhood illness, poverty, and frequent natural and man-made disasters and crises that erode household assets. Recognizing the need to address malnutrition in a broad way, the gardening and nutrition education activities were linked into the ongoing development programmes of the NGOs. To ensure sustainable development, strong linkages with the community are essential. NGOs are an important component of the development infrastructure in Bangladesh and have been on the forefront of working with communities. By working with women's groups, the NGOs have helped to address the social and cultural constraints that face women in Bangladesh. The large number of NGOs, their extended infrastructure throughout Bangladesh, and their emphasis on working with poorer households were complementary to the scale-up plans for the homestead gardening programme.

Gardening promotion through community support services

Local partner NGOs work with their community groups to establish village-level nurseries and homestead gardens. The village nurseries serve as a community support service network in such a way that they are the focal point for demonstration and training on low-cost, low-risk gardening practices for nursery holders, the leaders of the NGO women's groups, and household gardeners. In addition, they are the source and distribution centres for seeds, seedlings, and saplings, the sites for demonstration of new plant varieties, and the centres for community mobilization and organization. The majority of the village nurseries are operated as small enterprises and are a significant source of income for the household. In the expansion, each NGO is encouraged to form 45 village nurseries per subdistrict of approximately 15 decimals (600 square feet) that serve 5 to 10 villages. Five to 10 working groups of the NGOs of approximately 20 women each are linked to each nursery to participate in the gardening programme, and a group leader or selected individual is identified to develop and manage the nursery (fig. 1). The group leader also facilitates nutrition and health education through peer education among the women's groups. Helen Keller International provides training and technical assistance to the agriculturists and extension agents

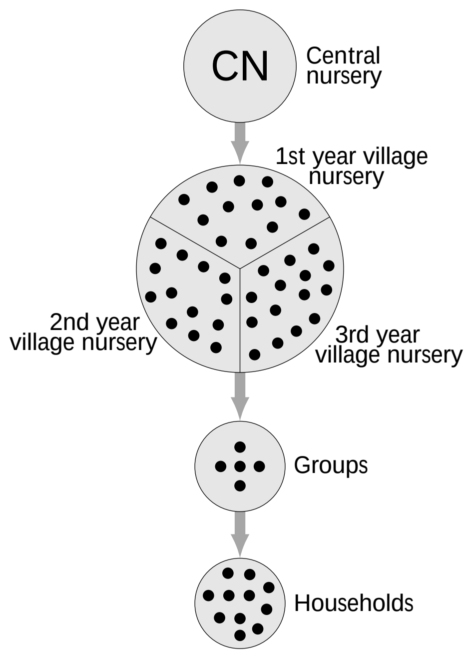

FIG. 1. Model for implementation of Bangladesh homestead gardening programme at the subdistrict level. In this model, each subdistrict has 1 central nursery, 45 village nurseries, and 4,500 households

of the partner NGOs. Technical assistance is provided by NGO and Helen Keller International agriculturists, extension agents, and nursery owners, based on the needs of the households and nursery owners, and is designed to reinforce and improve existing positive gardening and consumption practices.

Targeting

The selection of target groups has a major influence on the impact of the programme. The majority of NGOs form groups of functionally landless households (those owning less than 0.3 hectares of cultivable land) for their existing programmes, which include income-generating activities, non-formal education, health, and credit. The NGOs establish the number of groups, the population coverage and reach, and the size of the community group on the basis of their overall development strategy. The NGNESP (Non-Governmental Organization Gardening and Nutrition Education Surveillance Project) works within this existing structure and directly with the existing community groups of the NGOs, at times making minor modifications to include households with young children or households near the village nursery. Implementing the gardening activities within the NGO's infrastructure helps to ensure that households have access to multiple development services. Furthermore, gardening becomes an element of the NGO's development strategy and therefore is more likely to be sustained after three years of technical assistance from Helen Keller International.

Participation of women in gardening activities

Women in rural Bangladesh have traditionally managed homestead gardening, from sowing to harvesting and storing of seed. The involvement of women in this programme creates new employment opportunities for underprivileged women. In addition, women are generally the nutrition gatekeepers, i.e., the principal decision makers in procuring and preparing food for their children. Therefore, if women are targeted there is a greater likelihood that the vegetables will be consumed and, particularly, consumed by children. In the NGNESP, participation of women is strongly encouraged, but there is some variation in the focus and involvement of women, depending on the NGO's management and mandate. On average, 70% of the targeted households are represented by women.

Scale-up

In collaboration with 42 partner NGOs and the Government of Bangladesh, the NGNESP currently operates in 180 subdistricts throughout Bangladesh and reaches more than 700,000 households. Each year, new areas are added to the programme. A rigorous process has been developed to identify new areas and new partner NGOs to participate in the programme. The NGNESP is now working in the hilly terrain of the tea estates, in flood-prone areas, in peri-urban and urban slums, and in areas with high-saline soil. During the scale-up phase, the diversity of partner NGOs has also expanded and includes labour unions that work with marginalized female labourers in the tea gardens and local committees that work with households in the formally annexed area near Myanmar. The scale-up phase has stressed partner ownership of the programme by helping the NGOs incorporate homestead gardening and nutrition into their long-term development strategies. In order to encourage long-term sustainability of the NGOs' role in the homestead gardening programme, Helen Keller International has initiated a planning workshop to prepare a long-term plan for the inclusion of homestead gardening and nutrition education activities into the NGOs' mandates. In addition, the programme activities are co-financed by Helen Keller International and the NGOs over the three-year collaboration to implement the programme. This financial involvement reinforces ownership and sustainability of the programme. Regular reviews of lessons learned have led to modifications of the home gardening model and to the development of collaborations with other organizations.

Programme monitoring

Programme monitoring is an essential part of programme implementation and has been one of the key tools used to successfully scale up the Bangladesh homestead gardening programme. Monitoring activities are used to improve the performance of the programme by helping the NGOs and Helen Keller International to identify problems and priorities and develop solutions based on sharing between the beneficiaries and the programme staff. Helen Keller International monitors the programme activities regularly at the central nursery level, the village nursery level, and the household level. Simple questionnaires are developed to collect information on seed production, vegetable and fruit production, and income generated by nursery owners and household gardeners. Vegetable and fruit consumption is also included in routine monitoring. Monitoring is done together with partner organization staff, and these results are discussed immediately with the respective different levels of field staff. In addition to the monitoring of programme activities, Helen Keller International staff regularly supervise NGO field and management staff.

Changes in production and consumption

From the regular monitoring data obtained in 1997 and 1998, it has become evident that the programme has increased the production and consumption of fruits and vegetables in the working areas. The observed changes in household gardening practices after one year of programme participation are presented in figure 2. Household gardens are classified as "traditional," "improved," and "developed" on the basis of a number of criteria. Traditional gardens are scattered and seasonal and have only gourd types of vegetables, which are common in rural Bangladesh households. Improved gardens are those that have vegetables other than the gourd type but are not productive throughout the year. Developed gardens produce vegetables throughout the year, produce more varieties of vegetables, and are on fixed plots of land. Approximately 75% of households were practising homestead gardening, but nearly 60% had a traditional garden at the start of the programme. After one year of participation in NGNESP, the percentage of households who practised year-round (developed) gardening had increased significantly from 3% to 33% ($p < .001, \chi^2$ test). In addition, the percentage of households without a home garden decreased from 25% at baseline to less than 2% after one year ($p < .01, \chi^2$ test).

Figure 3 presents the frequency of vegetable consumption by children in the previous seven days, the number of varieties of vegetables produced, and the volume of production of vegetables in the last two months for different types of gardening practice. The volume of production and the number of varieties produced were highest among households who practised developed gardening. Children in households with developed gardens consumed vitamin A–rich foods, such as green leafy vegetables and yellow fruits, more frequently than did children in households without a garden or with a traditional garden. The number of varieties and the volume of production of vegetables were three times higher in households with developed gardens than in those with traditional gardens, and the consumption of vegetables by children was 1.6 times higher.

Routine monitoring data showed that households earned on average Taka 300±777 bimonthly (approximately US$8) by selling the fruits and vegetables. The principal use of this income was for food (table 1). The households also used the income from fruit and vegetable sales to invest in seeds, seedlings, saplings, poultry, or other income- generating activities, and nearly 10% of households saved the income generated from the garden. The majority of gardens (73%) were managed by women, and women were the main decision makers regarding gardening practices and use of the income earned by selling garden produce.

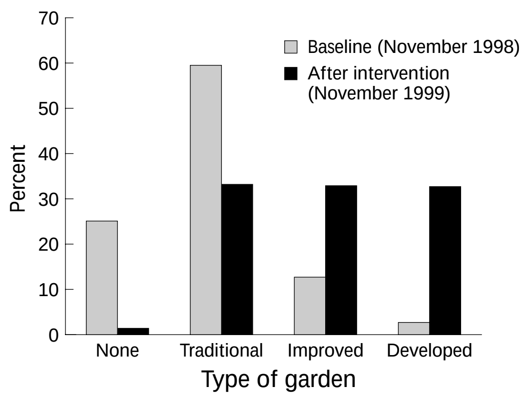

FIG. 2. Changes in gardening practices after one year of programme participation ($n = 622$)

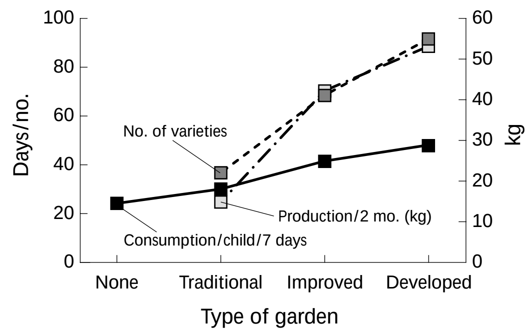

FIG. 3. Vegetable production and consumption according to type of garden ($n = 10{,}107$)

Discussion

Home gardening has been shown to be an important way to improve the intake of vitamin A–rich foods, particularly for poor households and in countries where plant foods are the main source of vitamin A. The pilot programme was initiated to identify ways to improve existing homestead gardening practices. Following the development of a community-based model, the programme was scaled up by forming partnerships with local NGOs. By implementing the programme through partnership with NGOs, households continued to receive technical support for homestead gardening, and the programme continued to expand without input and resources from Helen Keller International. The pro-

TABLE 1. Main uses of income earned by selling garden produce ($n = 10{,}107$)

Use	% of households
Food	56.3
Income-generating activities	15.3
Savings	9.7
Clothing	5.5
Education	4.8
Medicine	1.6
Housing	1.4
Amusement	0.4
Social activities	0.2
Other	4.8

gramme has been expanding from 1993 to the present, and to date it has worked with more than 40 NGO partners and reaches more than 700,000 households. Regular monitoring has demonstrated that the programme increases the production and consumption of vitamin A–rich foods in the targeted households. Recent findings from the national vitamin A survey have reconfirmed that children in households without a homestead garden are at greater risk for night-blindness than are children in households with a homestead garden [5].

On the basis of our experience, we have identified several important elements for successfully scaling up the home gardening programme in Bangladesh.

Pilot and local development of the programme

An innovative pilot study formed the basis for the structure and content of the national programme. By incorporation of the experience from the pilot study, the programme was developed on the basis of existing conditions, climate, and local culture. The programme promotes the use of local technology and modifications to local gardening practices rather than introducing external practices.

Partnership and flexibility in implementation

Helen Keller International and the partner NGOs have developed an effective collaboration that capitalizes on the strengths of both organizations. This partnership is initially formed through a planning workshop at the start of the programme and is maintained by regular sharing of information about the community, the programme outcomes, and other factors that affect the beneficiaries and the implementers. Helen Keller International maintains a high level of flexibility with the partner NGOs in implementation and management to maximize programme effectiveness and to encourage long-term sustained involvement of the NGOs in activities to improve the diets of women and children. The gardening activities are integrated with other health and development services of the NGO, and this integration leads to cost-effective development.

In order to manage the implementation of this complex programme, adequate human resources are essential. Management staff have been innovative and have successfully motivated programme staff to communicate and support programme activities. NGO staff work with gardeners, local nursery owners with the private seed sector, and senior management of the NGOs with Helen Keller International.

Simple, community-based access to gardening inputs

Access to the necessary inputs for gardening from a local, sustainable source is an important element for successful gardening. Seeds, seedlings, and saplings, a regular water system, environmentally friendly soil improvement techniques and pest control, live fencing, and credit or capital as necessary are some of these essential inputs. The source of these inputs needs to be steady and within access of those who need them most. In Bangladesh the village nurseries serve this role. The nurseries are used to demonstrate different varieties, hybrids, or other important garden techniques such as live fencing, use of botanical pesticides and fertilizers, and crop rotation practices. In other countries, the village nurseries might be replaced by local government agencies, the private sector, or other community-based structures.

Community participation

From the initial assessment of traditional homestead gardening practices, the involvement and participation of the community in programme design, implementation, and evaluation has been a key element of the success of the programme. Having a two-way channel for information exchange has been instrumental for achieving sustainable, improved gardening practices. Under the NGNESP, villages, households, and groups of women organize themselves, select the group leader, and plan the programme implementation.

Technical assistance, demonstration, and training

Helen Keller International has provided assistance for technical aspects of the programme, for programme management, and for planning of programme inputs such as seeds, water sources, and staffing. Technical assistance and support are especially important when new gardening techniques are being promoted, such as new varieties or year-round vegetable production.

Nutrition education and social marketing within the gardening activity

Experience shows that counselling to change feeding and eating behaviours is generally an important component of food-based strategies. Similar to understanding the indigenous approach to gardening, an understanding of the cultural context and feeding practices and constraints will guide nutrition education to achieve sustainable behavioural changes. The garden or nursery can also be used as a focal point for nutrition education and social marketing to promote increased consumption of micronutrient-rich foods. Messages about other issues that influence nutrient absorption and overall health can be presented to households and discussed among mothers and household members.

Programme monitoring

Monitoring serves as a tool for ensuring that activities are carried out as planned and to improve performance as required. It facilitates the identification of problems and the development of solutions that are based on sharing knowledge between the beneficiaries and the programme managers. Indicators are dependent on programme objectives and should include some information that can be monitored locally.

Continuous evaluation

Continued integration of lessons learned from implementation and evaluation efforts is one of the key aspects to the successful scale-up of this programme. As shown in figure 4, at key intervals in the programme, evaluation and planning were conducted to improve the programme. Within this programme system of implementation, evaluation, and planning, Helen Keller International operates a similar review process with each of the NGO partners over the three-year programme period through supervision and monitoring.

Future of the programme

The programme continues to expand in Bangladesh into new areas and to additional households in the current working areas. The gardening model has been adopted by the Government of the People's Republic of Bangladesh and has been part of a programme of the Department of Agriculture Extension. In 1997 Helen Keller International started the phaseout of technical and financial support to NGOs that have received three years of support from Helen Keller International. Monitoring information from these areas one year after the withdrawal shows that the households are maintaining their improved gardening practices and continue to consume fruits and vegetables more regularly [12]. In addition to further expansion and refinement of the gardening programme within Bangladesh, the approach described here is being used by Helen Keller International to develop homestead gardening programmes in Cambodia, Nepal, and Niger. Following on these important successes and lessons learned, many exciting challenges lie ahead: the development of innovative regional and national marketing systems for garden produce; the establishment of stronger linkages with commercial seed producers; integration of homestead gardening with other food production schemes; and investigation of how to use the gardening network to deliver other services, such as micronutrient supplements. Gardening is more profitable than cereal production, yet a major challenge for the future is to motivate farmers to shift from rice production to fruit and vegetable production. Differences in the quality of implementation of NGO partners, the spillover effect, the recent discovery that the bioavailability of vitamin A from plant sources is less than originally believed, and the new evidence from developed countries that vegetables and fruits have important roles in health and survival beyond the role of vitamin A will challenge how we measure the biological impact of these programmes. Finally, the impact of large-scale programmes needs to be evaluated by large-scale studies such as national surveys.

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We wish to acknowledge our NGO partners, who are truly partners in improving the social and economic development of poor households in Bangladesh. We express appreciation to the Government of the People's Republic of Bangladesh, particularly the Department of Agriculture Extension, which facilitated and supported the programme in the field implementation and in policy discussions. We also acknowledge support from other organizations working on food production in Bangladesh, such as the Food and Agriculture Organization and the Asian Vegetable Development and Research Center. We gratefully recognize generous financial

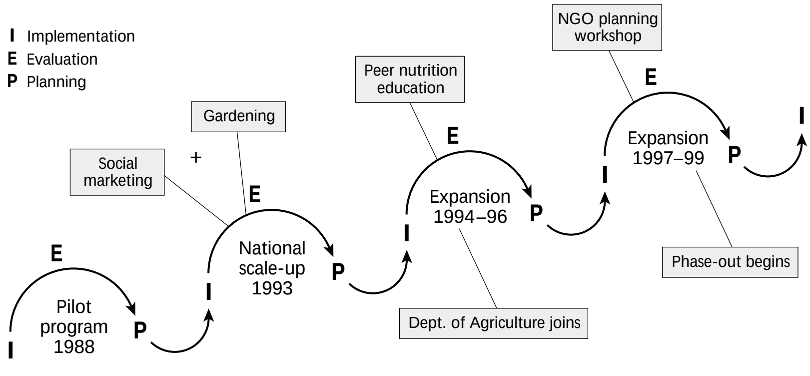

FIG. 4. Evolution of the Bangladesh homestead gardening programme

support from the US Agency for International Development and the Netherlands Organization for International Development Cooperation. We also thank the Australian Agency for International Development, which provided funding for the initial assessment study in 1988, without which the current programme might not have evolved. Reviews of this programme by external consultants have helped in the preparation of this article and have stimulated important modifications to the programme over the past 10 years.

References

1. Helen Keller International, Bangladesh, and Institute of Public Health Nutrition. Vitamin A status throughout the lifecycle in rural Bangladesh. Dhaka: Helen Keller International, 1999.
2. Wasantwisut E. Nutrition and development: other micronutrients' effect on growth and cognition. Southeast Asian J Trop Med Public Health 1997;28(Suppl 2):78–82.
3. Underwood B. From research to global reality: the micronutrient story. J Nutr 1998;128:145–51.
4. Ministry of Health and Family Welfare (MOHFW), Government of Bangladesh. Bangladesh National Plan of Action for Nutrition (NPAN). Dhaka: Bangladesh National Nutrition Council, 1997.
5. Kiess L, Bloem MW, de Pee S, Hye A, Khan T, Talukder A, Huq N, Haq N, Ali M. Bangladesh xerophthalmia free: the results of an effective VA capsule program and homestead gardening in reducing vitamin A deficiency. In: American Public Health Association 126th Annual Meeting Report, 15–18 November, 1998. Washington, DC: American Public Health Association, 1998:361 (abstract).
6. Cohen N, Jalil MA, Rahman H, Matin MA, Sprague J, Islam J, Davison J, Leemhuis de Regt E, Mitra M. Landholding, wealth and risk of blinding malnutrition in rural Bangladesh households. Soc Sci Med 1985;21:1269–72.
7. HKI NGO Gardening and Nutrition Education Surveillance Project (NGNESP) Monitoring Report, Round 12, October 1997 to January 1998. Dhaka: Helen Keller International, 1998.
8. Landauer K, Brazil M, eds. Tropical home gardens. Selected papers from an international workshop at the Institute of Ecology, Padajadjaran University, Indonesia. Tokyo: United Nations University Press, 1985.
9. Ramphal, Gill HS. Demand and supply of vegetable and pulses in South Asia. In: Vegetable research and development in South Asia: proceedings of a workshop in Pakistan, September 1990. Asian Vegetable Research and Development Center Publication No.90-331. Tainan, Taiwan, 1990:156–65.
10. Helen Keller International, Bangladesh/Asian Vegetable Research and Development Center, Taiwan. Home gardening in Bangladesh, evaluation report. Dhaka: Helen Keller International, 1992.
11. Bloem MW, Huq N, Gorstein J, Burger S, Kahn T, Islam N, Baker E, Davidson F. Production of fruits and vegetables at the homestead is an important source of vitamin A among women in rural Bangladesh. Eur J Clin Nutr 1996;50(3):S62–67.
12. Talukder A, Kiess L, Nihar. Sustainability of the Bangladesh homestead gardening program. Dhaka: Helen Keller International, 1999.

Underutilized β-carotene–rich crops of Vietnam

Le T. Vuong

Abstract

Solutions to micronutrient deficiencies that capitalize upon indigenous resources and foodstuffs offer a long-term mechanism for elevating the health status of disadvantaged people. In populations where intakes of animal foods are inadequate and food sources of retinol are not economically possible, efficient use of carotene-rich plants may prevent vitamin A deficiency. In Vietnam the gac *fruit (*Momordica cochinchinensis *Spreng) is an excellent source of β-carotene (17–35 mg per 100 g of edible portion). This fruit is familiar to indigenous people and is easy to grow. However, it has been underutilized because it is available only three months a year, there have been no efforts to educate the at-risk population about its nutritional benefit, and research efforts in production or preservation techniques have been lacking. This paper describes the fruit, compares its nutritional value with that of familiar carotenoid-rich fruits, details its traditional usage in preparing rice, and discusses the acceptance of this rice preparation (*xoi gac*) by Vietnamese preschoolers in their daily diet. Financial support for research directed at improving the production and preservation of indigenous β-carotene–rich crops is needed to alleviate the problem of vitamin A deficiency of children in northern Vietnam.*

Introduction

In the battle against malnutrition, chronic vitamin A deficiency stands out as one of the most resistant nutritional problems in developing countries, in spite of the fact that the symptoms are not difficult to identify, the aetiology is well understood, treatments are available, and in most cases a food source of retinol and provitamin A carotenoids is plentiful.

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Vitamin A deficiency in Vietnam

The problem of vitamin A deficiency among children was first recorded in Vietnam in 1958, with 1,502 hospitalized cases of keratomalacia in the northern region between 1951 and 1953 [1]. However, it was not until 1985, when the prevalence of vitamin A disorders in school-age children exceeded the World Health Organization (WHO) cut-off point criterion for a public health problem, that vitamin A deficiency in Vietnam received international attention. This triggered measures to control the problem, and a programme was begun to distribute high-dose vitamin A capsules to children under two years of age in all provinces in 1990 [2–4]. Nevertheless, chronic vitamin A deficiency persists as one of the prevailing nutritional problems among children in the rural areas of Vietnam [5]. Physiologically, subclinical deficiencies manifest as susceptibility to infection and growth retardation [6, 7]. As a public health issue, such widespread infirmities in developing countries have a human and economic cost equal to or higher than that of the more advanced stages of deficiency.

Vitamin A distribution programmes do not provide a long-term solution in the rural areas of Vietnam, for a number of reasons. Distribution in remote areas is difficult and fragmentary, and can further be confounded by the unstable sociopolitical factors common to emerging countries. Such programmes are frequently not available to all age groups of children or to women of reproductive age. For people of lower economic groups and inhabitants of rural areas, animal products, which can be the best sources of vitamin A, are not available in sufficient abundance to prevent vitamin A deficiency. Our dietary assessment of 193 preschoolers in two communities of northern Vietnam in 1997 found that daily consumption of meat was less than 15 g per child [8]. A national survey among 13,000 children in northern Vietnam in 1991 reported that consumption of vegetables and fruits among children with xerophthalmia provided 13% of total energy, significantly lower than that among children without xerophthalmia (24%) [9].

Plant food as a source of provitamin A

In the diet, vitamin A comes in two forms: preformed vitamin A and provitamin A. Preformed vitamin A is usually in the form of retinyl ester, derived from animal tissues such as eggs, fish oils, and flesh and organ meats. Milk, cream, butter, cheese, and fortified foods such as margarine also contain vitamin A. Vitamin A can also be obtained from provitamin A carotenoids, which can be converted enzymatically in the intestine and liver to retinol. Carotenoids in plants are the primary dietary source of vitamin A worldwide [10, 11]. The most efficient provitamin A carotenoid is β-carotene, which is abundant in yellow and orange fruits, such as mangoes, papayas, and yams, and in green leafy vegetables, such as spinach, kale, sweet potato leaves, and sweet gourd. Consumption of foods rich in β-carotene theoretically can replete people to a healthy vitamin A status [12–17].

In the winter of 1997 and the summer of 1998, dietary assessment, household gardens, and market surveys were conducted in two communes in the lowlands of northern Vietnam. The fruits and vegetables that are available are listed in table 1. Among the indigenous plants of northern Vietnam, the *gac* fruit (*Momordica cochinchinensis* Spreng) has the highest β-carotene content (fig. 1). Provitamin A from orange fruits has been

TABLE 1. Summer and winter fruits and vegetables in northern Vietnam

Vietnamese name	English name	Latin name
Rau lang	Sweet potato leaves	*Ipomoea batatas*
Rau mong toi	Ceylon spinach	*Basella rubra*
Rau muong	Water spinach	*Ipomoea aquatica*
Rau day	Jute potherb	*Corhorus olitorius*
Rau ngot	Sauropus leaves	*Sauropus androgynus*
Rau bi	Pumpkin leaves	*Cucurbita pepo*
Rau cai cuc	Chrysanthemum	*Chrysanthemum coronatium*
Rau cai soong	Watercress	*Nasturtium officinale*
Rau cai xanh	Mustard greens	*Brassica juncea*
Rau cai bap	Cabbage	*Brassica oleracea*
Rau can	Celery water	*Oenanthe stolonifera*
Rau cai thia	Chinese cabbage	*Brassica spp.*
Rau rut		*Neptunia oleracea*
Gia	Mungbean sprouts	*Vigna radiata*
Khoai lang	Sweet potato	*Ipomoea batatas*
Ngo	Corn	*Zea mays*
Hanh	Onion	*Allium cepa*
Ca chua	Tomato	*Solanum lycopersicum*
Ca rot	Carrot	*Daucus carota*
Xu hao	Kohlrabi	*Brassica oleracea*
Ca bat	Aubergine	*Solanum melongena*
Ca phao	Eggplant	*Solanum melongena*
Bi do	Pumpkin	*Cucurbita pepo*
Bi xanh	Ashgourd, waxgourd	*Benincasa cerifera*
Khoai tay	Potato	*Solanum tuberosum*
Muop dang	Bitter melon	*Momordica charantia*
Bac ha		*Colocasia indica*
Gac	Spiny gourd	*Momordica cochinchinensis*
Muop	Sponge gourd	*Luffa cylindrica*
Mang	Bamboo shoots	*Bambusa* spp.
Du du	Papaya	*Canca papaya*
Chuoi	Banana	*Musa sapientum*
Quit	Madarin orange	*Citrus reticulata*
Buoi	Grapefruit	*Citrus maxima*
Vai	Lychee	*Litchi sinensis*
Dua	Pineapple	*Ananas sativus*
Chanh	Lemon	*Citrus limon*
Ot	Chili pepper	*Capsicum frutescens*
Cam	Orange	*Citrus sinensis*
Khe	Star fruit	*Averrhoa carambola*
Dua hau	Watermelon	*Citrullus vulgaris*
Dua chuot	Cucumber	*Cucumis sativus*
Dua gang	Large cucumber	*Cucumis melo*

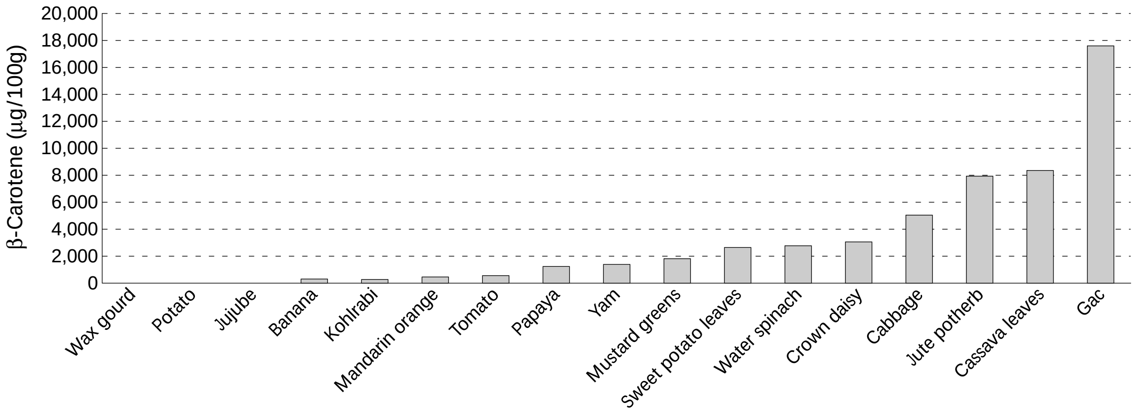

FIG. 1. β-Carotene contents of gac and other commonly consumed fruits and vegetables in northern Vietnam. Source: refs. 18 and 19

shown to be more bioavailable than that from dark-green leafy vegetables [20]. The seed membrane and pulp of the gac fruit also contain a significant amount of oil, which is essential for the absorption and transport of β-carotene [21–23]. This is especially critical in this population, where dietary fat intake is very low [24]. Traditionally, gac seed and pulp are mixed with cooked rice to impart a red colour and distinct flavour [25–27]. The local name of the dish is *xoi gac*. Because this dish is already well accepted, promoting its consumption could produce a substantial increase in β-carotene intake.

Momordica cochinchinensis Spreng (gac) is botanically classified as Family Cucurbitaceae, Genus *Momordica*, Species *cochinchinensis*. This rampagenous perennial vine was given the name *Muricia cochinchinensis* by Loureiro, a Portuguese missionary priest who published *Flora Cochinchinensis* in 1790. Later, Sprengel concluded that the plant belonged in the Linnaean genus *Momordica* and changed the name in 1826 [28]. The Vietnamese name of *Momordica cochinchinensis* Spreng is *day gac* [25–27, 29–30]. *M. cochinchinensis* is also indigenous to China, the Moluccas (Burma), Japan, India, Thailand, Laos, Cambodia, the Philippines, Malaysia, and Bangladesh [30–32]. Other common names of the plant are listed in table 2.

The plant can be cultivated either from seeds or from root tubers. The leaves are alternate and deeply three- to five-lobed with toothed margins. The leaf stalk is glandular. The gac plant is dioecious, that is, the male and female plants are separate. The flowers are pale-yellow and solitary in the axils of the leaves (fig. 2). The production of parthenocarpic fruits, which is of economic importance, can be accomplished using growth regulators in the female plant in the absence of male plants. However, induced parthenocarpic fruits have no seed, whereas hand-pollinated fruits contain 18 seeds per fruit on average [33].

The plant starts flowering about two months after root tubers have been planted. Flowering usually occurs in April and continues to July and August and sometimes until September. On average, it takes about 18 to 20 days for a fruit to mature from emergence of the bud of the female flower. A plant produces 30 to 60 fruits on average in one season. The ripe fruit is picked from August to February [34].

The fruits of *M. cochinchinensis* are large, densely aculeate, and green, turning to dark orange or red when ripe. Unlike that of the bitter gourd (*Momordica charantia*), the exocarp (rind) of the gac fruit is hard and is covered with conical points one-eighth-inch high. The gac fruit available in Vietnam comes in oblong and almost round shapes. There are no differences in the ways these two types of fruit are used or consumed.

TABLE 2. Names of *Momordica cochinchinensis* in different languages

Language	Name
Latin	*Momordica cochinchinensis* Spreng *Muricia cochinchinensis* Lour. *Muricia mixta* Roxb.
Chinese	Moc niet tu
English	Spiny bitter gourd Sweet gourd Cochinchin gourd
Japanese	Kushika Mokubetsushi
Hindi	Hakur Kakrol Kakur
Laotian	Mak kao
Malay	Teruah
Thai	Fak kao
Vietnamese	Gac

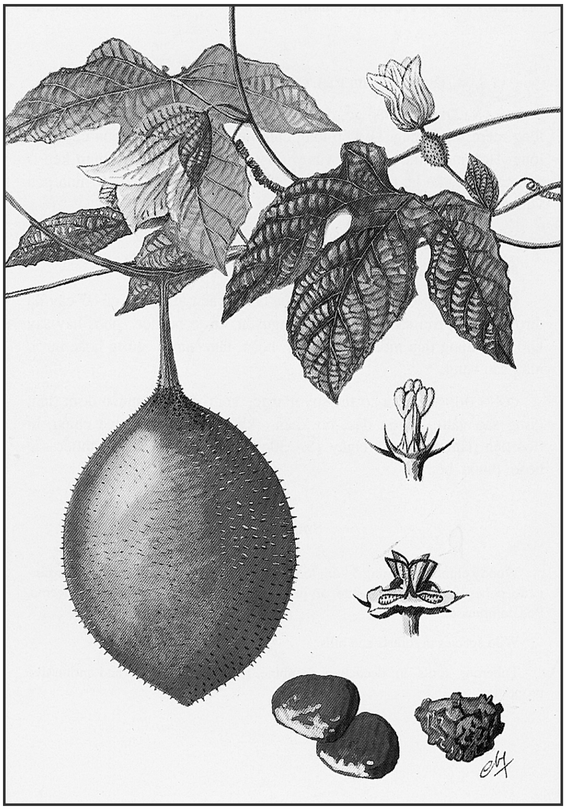

FIG. 2. *Momordica Cochinchinensis Spreng* (gac) flowers, leaves, fruit, and seeds. Reproduced from ref. 34

There are also variations among different fruits with respect to their spines and fruit tips. In some fruits the spines are smooth and dense, whereas in others they are hard and widely spaced. The oblong types are 6 to 10 cm in length, and the round types are 4 to 6 cm in length. In Vietnam the oblong fruit weighs between 500 and 1,600 g and can be 10 to 13 cm long. Shadeque and Baruah reported that in Assam the fruit weighs from 1 to 3 kg [35]. Unlike bitter gourd, which is mostly harvested in the developmental stages, gac fruits in Vietnam are only picked at maturity when the fruit is bright red and the seeds are hardened.

The mesocarp of the *M. cochinchinensis* fruit is one-half-inch thick, spongy, and orange. The core is divided into cartilaginous chambers containing bright-red fleshy seed pods (fig. 3). Each fruit has on average between 15 and 20 round, compressed, and sculptured seeds. The seed membrane and kernels contain oil and are used in traditional medicine [25–27, 32]. There is no record of any use of the mesocarp. The average weight of the pulp is about 19% of the total fruit weight. An average gac fruit weighing 1 kg yields approximately 190 g of fruit pulp and 130 g of seeds. The seed pulp of a ripe fruit is bright red and has a palatable bland to nutty taste.

FIG. 3. Sectioned gac fruit showing many red seeds inside

Nutritional composition of *M. cochinchinensis* seed pulp

Carotenoid was first identified in gac fruit by Guichard and Bui in 1941 [29]. A Vietnamese publication reported that 100 g of gac pulp contained 45,780 μg of β-carotene [27]. Our chemical analyses of carotene contents in gac pulp have been described elsewhere [8]. In ripe gac fruit, β-carotene is the dominant carotenoid, with a concentration as high as 35,500 μg per 100 g of edible portion. The mean concentration of β-carotene in gac fruit from four separate HPLC (high-performance liquid chromatography) assays was 26.06 ± 9.38 mg per 100 g. In addition to β-carotene, lycopene was the only carotenoid present in quantifiable amounts. West and Poortvliet reported a concentration of 18,810 μg of β-carotene per 100 g and 89,150 μg of total carotenoids per 100 g [18].

In addition to carotene, gac pulp contains a significant amount of oil. Fatty acid analyses indicate that gac contains 852 mg per 100 g of edible portion. Of the total fatty acids in gac pulp, 70% are unsaturated, and 50% of these are polyunsaturated. The approximate nutrient composition of gac fruit and pulp is shown in table 3, and the fatty acid composition of gac pulp is given in table 4.

Traditional uses of gac fruit in Vietnam

In Vietnam, the gac vine is often seen growing on lattices at the entrances of rural homes. The Vietnamese use the seed membranes and the pulp of the fruit in the preparation of *xoi gac* (red rice) [25–27, 29]. Traditionally, xoi gac is served at weddings, the New Year (Tet), and other important celebrations [27]. During these occasions, it is essential to mask the white colour of rice, since white is considered the colour of death. To make xoi gac, the pulp of gac fruit is mixed with rice. The seeds are often left in the rice as proof of authenticity (fig. 4). The colour and fatty acids from the fruit pulp and seed membrane are stirred into the rice,

TABLE 3. Approximate nutrient composition of *Momordica cochinchinensis* Spreng

Nutrient	Content/100 g edible portion	
	Fruit[a]	Seed pulp[b]
Water (%)	90.2	7
Energy (kcal)	29	125
Carbohydrate (g)	6.4	10.5
Protein (g)	0.6	2.1
Fat (g)	0.1	7.9
Fibre (g)	1.6	1.8
Ash (mg)		0.7
β-Carotene (μg)		45,780
Ca (mg)	27	56
P (mg)	38	6.4

a. From ref. 52.
b. From ref. 19.

FIG. 4. Xoi gac, a preparation of white rice reddened by the gac pulp. Seeds are left in the rice as a proof of authenticity

giving it a lustrous appearance and oil-rich taste. The name xoi gac means red rice, and when the gac fruit is not in season, rice with red food colourant is also called xoi gac, which local people occasionally eat for breakfast. In addition to their use in xoi gac, the seed membranes are used to make a tonic (gac oil) for lactating or pregnant women and children, and to treat "dry eyes" (xerophthalmia) and night-blindness. Vo reported that when applied to wounds, skin infections, and burns, gac oil stimulated new growth of skin and closure of wounds [25]. A document on Vietnamese traditional medicine lists the use of the gac seed membrane, which contains β-carotene and lycopene, to treat infantile rachitis, xerophthalmia, and night-blindness. The report notes that the oil extract from the seed membrane can be given to small children to improve growth [26].

Supplementation trial

A supplementation trial was conducted from December 1997 to February 1998 in Hai-Hung Province, northern Vietnam. The objective of the trial was to assess the efficacy of the traditional β-carotene–rich rice preparation known as xoi gac for improving the vitamin A status of children in rural Vietnam. The length of the supplementation period was 30 days. The participants were 193 village children from 31 to 70 months of age in two communes of Hai-Hung Province, Doan-Ket and Tan-Trao. The children were selected from 711 village children in the above age groups. Selection criteria included low haemoglobin concentration (100–120 g/L), which has been associated with vitamin A deficiency [36–38]. The selected children were assigned to one of

TABLE 4. Fatty acid composition of gac pulp

Abbreviation	Name	Content (mg/100 g edible portion)	% total fatty acids	Type
14:0	Myristic	7.44	0.87	Saturated
16:0	Palmitic	187.86	22.04	Saturated
16:1	Palmitoleic	2.23	0.26	Unsaturated
18:0	Stearic	60.16	7.06	Saturated
18:1n9	Oleic	290.43	34.08	Monounsaturated
18:1n7	Vaccenic	9.67	1.13	Monounsaturated
18:2	Linoleic	267.86	31.43	Polyunsaturated
18:3n3	α-Linolenic	18.28	2.14	Polyunsaturated
20:0	Eicosanoic	3.32	0.39	Saturated
20:1	Gadoleic	1.25	0.15	Monounsaturated
20:4	Arachidonic	0.84	0.10	Polyunsaturated
22:0	Docosanoic	1.65	0.19	Saturated
24:0	Tetracosanoic	1.20	0.14	Saturated
	Total	852.19		

three groups: a fruit group that received rice cooked with gac containing 3.5 mg of β-carotene, a powder group that received rice mixed with synthetic β-carotene powder containing 5 mg of β-carotene, and a control group that received rice without fortification. The usual vitamin A and carotenoid intakes were assessed by a food-frequency questionnaire administered to the child's mother before and after supplementation.

Results

Plasma micronutrient concentrations

After the children's initial weights and β-carotene values had been controlled for, the mean increases in plasma β-carotene concentration among children in the fruit group (106 µg/dl; 95% confidence interval, 93–119 µg/dl) and the powder group (83 µg/dl; 95% confidence interval, 66–101 µg/dl) were significantly greater than those among control children (5 µg/dl; 95% confidence interval, 2–7) µg/dl). The increase in plasma lycopene concentration was significantly higher in the fruit group (940%) than in either the control (99%) or the powder groups (386%). Plasma retinol concentrations increased significantly in all three groups compared with initial values; the increase was highest in the fruit group but was not significantly different from that in the other two groups. After supplementation, 52% of the children in the fruit group and 47% of those in the powder group reached an adequate haemoglobin concentration (120 g/L). Changes in the haemoglobin concentration of children with a baseline value less than 110 g/L were significantly greater in the fruit group than in the control group (mean difference, 16.62 g/L; $p < .05$).

Acceptance of xoi gac by the children

All children completed the 30-day feeding programme. The attendance of children and mothers at the feeding centre was 100%. One hundred forty-six children (76%) completed the entire portion (about 120 g) every day of the study. The number of children who consumed the entire amount increased as the programme progressed, and on the last day of supplementation most children expressed disappointment about the termination of the programme. Eighty-four percent of the children in the fruit group, 72% of those in the powder group, and 76% of those in the control group completely consumed the food. More children in the fruit group than in the other two groups consumed the entire amount every day, but the difference was not statistically different.

Mothers' health perception and usual consumption of xoi gac

Ninety-five percent of the mothers interviewed recognized that xoi gac is nutritious, and 66% said that their children had consumed xoi gac since the beginning of the season. Eighty-four percent of the women prepared xoi gac themselves, 4% purchased it at the market, and 2% received it as a gift. Few households in the villages grew gac. Among the mothers who prepared xoi gac at home, only 23% used gac from their home gardens, 98% purchased gac from the market, and only 1% received gac as a gift. Among the 46% of the mothers who did not give xoi gac to their children, 74% said that they did not have gac fruit, 3% said that did not have money to buy gac, 4% said that they did not have time to cook xoi gac, and only 3% reported that the children did not like xoi gac.

The results of the trial suggest that xoi gac is well accepted by the children. The provitamin A from xoi gac, a rich source of β-carotene and lycopene, is highly bioavailable, and severely anaemic children might benefit from β-carotene supplementation.

Discussion

Underutilization of gac fruit in Vietnam

Production and consumption of *M. cochinchinensis* (gac) fruit in northern Vietnam in recent years has decreased for the following reasons. The local people have a poor perception of the health and commercial benefits of the plant. There have been no efforts to promote the production of gac fruit and educate the target population about its nutritional benefits. Consequently, land is allocated to cultivation of staples or crops that bring greater commercial benefits, such as onion, black pepper, or potatoes. This situation has been observed in other regions of the world [39]. Traditional micronutrient-rich plant foods have become less abundant and more expensive because their production has fallen or not kept abreast with demand because of increased population pressure. In fact, in many nations in Asia, consumption of vegetables has not met the recommended value of 73 kg per year per person, the minimum amount needed to prevent micronutrient malnutrition. Meanwhile, there has been a greater research focus on increasing the production of calorie-rich staple crops such as rice, wheat, corn, and cassava [40].

The gac fruit is only available three months out of the year. In Vietnam gac vines are grown mainly in the Red River Delta area. Harvesting of the fruits begins in September and lasts until December. Gac fruits are picked when they are of optimal size, weight, and colour. Poor post-harvest handling and transportation reduce the shelf-life of the fruit. After harvesting, fruits perish quickly and lose marketability after one week without proper storage. In the markets of urban areas, gac fruits are available for only about three months, from November to January. A survey of mothers of participants in the supplementation trial revealed that the main reason that mothers did not feed xoi gac to their children was the unavailability of gac. The use of gac fruit in making xoi gac has declined, because synthetic food colourant is more available and economical. The consumption of gac fruit will be increased if gac fruit is more available. Gac pulp can be simply preserved in sugar, oil, or alcohol, but there has been no effort to promote or improve preservation of the fruit.

Improving the availability of indigenous nutrient-rich plants to prevent micronutrient malnutrition

The problems encountered in most food-based approaches to improving micronutrient status are multifaceted. They include concerns about nutrient concentrations and interactions in the selected food; bioavailability and bioconversion of the nutrient of interest; and issues related to cultural sensitivity [41–43]. Despite those problems, solutions to micronutrient malnutrition that make use of local food sources offer many benefits. The most apparent advantage is the self-sustainability of the programme. Another benefit is that the foods provide not only the deficient nutrients but also calories and other nutrients. Another attribute of long-term success of a food-based strategy is ready acceptability to target groups due to familiarity. Improved production of the foods will motivate the advancement of methods of processing, storing, and preserving the foods, which in turn not only will improve the availability of the foods but also will increase household income, which quite often is positively correlated with low nutritional status.

In the attempt to prevent micronutrient deficiency in developing countries by food-based strategies, most efforts have been spent on fortifying foods with synthetic ingredients or supplying foods that provide the needed nutrients to populations, rather than finding local sources of foods that contain the needed nutrients and promoting local production of those foods. Fortification requires centralized, well-monitored food processing and effective distribution channels; this type of infrastructure is often rudimentary in third world countries. Fortification with certain nutrients also changes the appearance and taste of the food and renders it less desirable to the target population. The fortification of sugar, monosodium glutamate, and fish sauce has been tested in several countries in Latin America and South-East Asia. None of the above fortification methods provides a sustainable solution to vitamin A deficiency in developing countries. Daily supplementation of needed micronutrients to prevent deficiency requires the commitment of suppliers, which are often foreign sources, and is usually not appropriate to the local food habits; hence this should only be a short-term measure.

Although the consumption of calories by people in developing nations has increased since the 1960s, the focus on staple crops, such as rice and wheat, has resulted in the decreased availability of micronutrient-rich food crops to millions of disadvantaged people and contributed to the increase in micronutrient malnutrition (“hidden hunger”) globally [40, 44]. To rectify the problem of vitamin A deficiency in developing countries, research efforts need to be directed towards identifying local plant foods rich in provitamin A carotene (in addition to staple crops), traditional use of the plants, and methods to improve production and preservation. Compilations of plants available in South-East Asia and their carotenoid contents have been made available by the work of numerous researchers [18, 45–47]. For many of these plants, the local use should be identified, because cooking and storing methods can change the bioavailability of carotenoids to humans [48]. Advanced food-processing techniques can be applied to facilitate beneficial local usage, such as the use of provitamin A carotenoid–rich plants for colouring rice or for seasoning foods. Environmental appropriateness and the plant matrix are also important factors in the bioavailability of β-carotene and should be considered in the selection of plant sources of β-carotene [21, 49]. Genetic manipulation of plant genomes, either by traditional plant breeding or by genetic engineering, has been applied to characterize the genes that control the biosynthesis of carotenes in tomatoes, maize kernels, and carrots [50, 51]. Currently these methods are under investigation to increase the amount of provitamin A carotenoids in staple foods (rice and cassava) [39]. These technologies and knowledge can be applied to improve the shelf-life of local crops rich in provitamin A carotenoids, to provide continuously and currently available provitamin A in fruits and vegetables, to overcome environmental stress, and to enhance the marketability of indigenous fruits. Commercial and nutritional benefits will encourage the cultivation of these carotene-rich crops, and their sustainability will be achieved by maintaining sensible local traditions.

References

1. McLaren D. Global occurrence of vitamin A deficiency. In: Bauernfield JC, ed. Vitamin A and its controls. New York: Academic Press, 1986:1–18.
2. Ha KH, Nguyen KC, Pham TD, Nguyen AT, Hoang AM. The impact of high-dose vitamin A supplementation on morbidity and nutritional status of young children: a commune-based trial. In: Proceedings of the international symposium on nutrition in primary health care in developing countries. Hanoi, Vietnam: UNICEF, 1991:195–203.
3. Tu G, Nguyen TN. Programme for the control of vitamin A deficiency and xerophthalmia in Vietnam. In: Proceedings of the international symposium on nutrition in primary health care in developing countries. Hanoi, Vietnam: UNICEF, 1991:189–94.
4. Tu G, Ha KH, Nguyen NT, Dricot JM. Control of vitamin A deficiency and xerophthalmia in Vietnam. In: Proceedings of the national symposium and XIII International Vitamin A Consultative Group meeting, Kathmandu, Nepal, 5–10 November. Kathmandu: IVACG, 1989:109–10.
5. Ha-Huy-Khoi. Tong quan tinh hinh dinh duong o Vietnam [The general nutrition situation of Vietnam]. In: Vien DD, ed. Proceedings of the national symposium on nutrition. Hanoi, Vietnam: UNICEF, 1996:1–9.
6. Filteau SM, Tomskin MA. Micronutrients and tropical infections. Trans R Soc Trop Med Hyg 1994;88 (Suppl 1):1–3.
7. Sommer A, West KP Jr. Vitamin A deficiency: health, survival and vision. New York: Oxford University Press, 1996:63–79.
8. Vuong LT. *Xoi Gac*, a rice preparation containing β-carotene from *Momordica cochinchinensis* Spreng (*gac*) for the prevention of vitamin A deficiency of children in northern Vietnam. Doctoral Dissertation, University of California, Davis, Calif, USA, 1998:78–100.
9. Tu G, Duong HD. The ecosystem VAC as a means to solve the food problem in Vietnam. In: Proceedings of the international conference on applied nutrition. Hanoi, Vietnam: UNICEF, 1986:66–80.
10. Bauernfield JC. Carotenoid vitamin A precursors and analogs in foods and feeds. J Agric Food Chem 1971; 20:456–73.
11. Teply LJ. Control of vitamin A deficiency by the agricultural crop and household food approach. In: Bauernfield JC, ed. Vitamin A and its controls. New York: Academic Press, 1986:319–23.
12. Bloem MW, Huq N, Gorstein J, Burger S, Kahn T, Islam N, Baker S, Davidson F. Production of fruits and vegetables at the homestead is an important source of vitamin A among women in rural Bangladesh. Eur J Clin Nutr 1996;50(Suppl 3):S62–7.
13. Charoenkiatkul S, Valyasevi A, Tontisirin K. Dietary approaches to the prevention of vitamin A deficiency. Food Nutr Bull 1985;7:72–6.
14. Devadas RP, Murthy NK. Biological utilization of β-carotene from amaranth and leaf protein in preschool children. World Rev Nutr Diet 1978;31:159–61.
15. Devadas RP, Premakumari S, Subramaniam G. Biological availability of β-carotene from fresh and dried green leafy vegetables on pre-school children. Indian J Nutr Diet 1978;15:335–40.
16. Lion OK, Tie LT, Rose CS, Prawiranegara DD, Gyorgy P. Red palm oil in the prevention of vitamin A deficiency. A trial on preschool children in Indonesia. Am J Clin Nutr 1967;20:1267–74.
17. Devadas RP, Sajora S, Murthy NK. Availability of β-carotene from papaya fruit and amaranth in preschool children. Indian J Nutr Diet 1980;17:41–4.
18. West CE, Poortvliet EJ. The carotenoid content of foods with special reference to developing countries. Washington, DC: US Agency for International Development, 1993.
19. Vien DD, ed. Thanh phan dinh duong thuc an Viet Nam [Food products in Vietnam composition and nutritive value]. Hanoi, Vietnam: Nha Xuat Ban Y Hoc, 1995.
20. de Pee S, West CE, Permaesih D, Martuti S, Muhilal, Hautvast JGAF. Orange fruit is more effective than are dark-green, leafy vegetables in increasing serum concentration of retinol and β-carotene in schoolchildren in Indonesia. Am J Clin Nutr 1998;68:1058–67.
21. Van Vliet T. Absorption of β-carotene and other carotenoids in humans and animal models. Eur J Clin Nutr 1996;50(Suppl 3):S32–7.
22. Dimitrov NV, Meyer C, Ullrey DE, Chenoweth W, Michelakis A, Malone W, Boone C, Fink G. Bioavailability of β-carotene in humans. Am J Clin Nutr 1988;48:298–304.
23. Goodman D. The intestinal absorption and metabolism of vitamin A and β-carotene in man. J Clin Invest 1966;45:1615–23.
24. Vuong L, Nguyen H, Keen C, Grivetti L. Dietary habits, consumption patterns and the problem of goiter: a study in Hai-Hung, northern Vietnam. FASEB J 1995;9:A165 (Abstract).
25. Vo V-C. Tu dien cay thuoc Viet Nam [A dictionary of medicinal plants of Vietnam]. Ho Chi Minh City, Vietnam: Nha Xuat Ban Y Hoc, 1997.
26. Vu DT. 100 cay thuoc, van linh ba chung [100 medicinal plants, highly effective for many diseases]. Hanoi, Vietnam: Y Hoc Viet-Nam Hoi Huu Xuat Ban, 1986.
27. Do TL. Nhung cay thuoc va vi thuoc Viet Nam [Medicinal plants and drugs of Vietnam]. Hanoi, Vietnam: Nha Xuat Ban Khoa Hoc va Ky Thuat, 1991.
28. Bailey LH. The garden of the gourds. New York: Macmillan, 1937:121–2.
29. Guichard F, Bui DS. La matière colorante du fruit du *Momordica cochinchinensis* Spr. Annales de l'Ecole Supérieure de Médecine et de Pharmacie de l'Indochine 1941;V:141–2.
30. Nguyen DV. Medicinal plants of Vietnam, Cambodia and Laos. Westminster, Calif, USA: Mekong Printing, 1998.
31. Herklots GAC. Vegetables in South-East Asia. London: George Allen & Unwin, 1972:338–9.
32. Perry LM. Medicinal plants of East and Southeast Asia, attributed properties and uses. Cambridge, Mass, USA: MIT Press, 1980.
33. Vijay OP, Jalikop SH. Production of parthenocarpic fruit with growth regulators in Kakrol (*Momordica cochinchinensis* Spreng). Indian J Horticulture Bangalore 1980; 37(2):167–9.

34. World Health Organization. Medicinal plants in Vietnam. Hanoi, Vietnam: Science & Technology Publishing House, 1990:247.
35. Shadeque A, Baruah G. Sweet gourd: a popular vegetable of Assam. Indian Farming 1984;34:25–35.
36. Amine EK, Correy J, Hegsted DM, Haynes KC. Comparative hematology during deficiencies of iron and vitamin A in the rat. J Nutr 1998;100:1033–40.
37. Bloem MW, Wedel M, Egger RJ, Speek AJ, Schrijver J, Saowakontha S, Schreurs WH. Iron metabolism and vitamin A deficiency in children in northeast Thailand. Am J Clin Nutr 1989;50:322–8.
38. Roodenburg AJ, West CE, Hovenier R, Beyner AC. Supplemental vitamin A enhances the recovery from iron deficiency in rats with chronic vitamin A deficiency. Br J Nutr 1996;75:623–36.
39. Graham RD, Welch RM. Breeding for staple food crops with high micronutrient density. Working Papers on Agricultural Strategies for Micronutrients, No. 3. Washington, DC: International Food Policy Research Institute, 1995:9–80.
40. Welch RM. Agronomic problems related to provitamin A carotenoid-rich plants. Eur J Clin Nutr 1997;51:S34–8.
41. Combs GF Jr, Welch RM, Duxbury JM, Uphoff NT, Nesheim MC, eds. Food-based approaches to preventing micronutrient malnutrition: an international research agenda. Ithaca, NY, USA: Cornell University Press, 1996.
42. Food and Agriculture Organization of the United Nations. Preventing micronutrient malnutrition: a guide to food-based approaches. A manual for policy makers and programme planners. Washington, DC: FAO and International Life Sciences Institute, 1997.
43. Solomons NW, Bulux J. Plant sources of vitamin A and human nutrition revisited: recent evidence from developing countries. Nutr Rev 1994;52:62–4.
44. Maberly GF, Trowbridge FL, Yip R, Sullivan KM, West CE. Programs against micronutrient malnutrition ending hidden hunger. Annu Rev Public Health 1994;5:277–301.
45. Michaud DS, Giovannucci EL, Ascherio A, Rimm EB, Forman MR, Sampson L, Willett WC. Associations of plasma carotenoid concentrations and dietary intake of specific carotenoids in samples of two prospective cohort studies using a new carotenoid database. Cancer Epidemiol Biomarkers Prevent 1998;7:283–90.
46. Ritenbaugh C, Peng YM, Aickin M, Graver E, Branch M, Alberts DS. New carotenoid values for foods improve relationship of food frequency questionnaire intake estimates to plasma values. Cancer Epidemiol Biomarkers Prevent 1996;5:907–12.
47. Mangels AR, Holden JM, Beecher GR, Forman MR, Lanza E. Carotenoid content of fruits and vegetables: an evaluation of analytic data [published erratum appears in J Am Diet Assoc 1993;93:527]. J Am Diet Assoc 1993; 93:284–96.
48. Rahman MM, Wahed MA, Ali MA. β-Carotene losses during different methods of cooking green leafy vegetables in Bangladesh. J Food Comp Anal 1990;3:47–53.
49. de Pee S, West CE. Dietary carotenoids and their role in combating vitamin A deficiency: a review of the literature. Eur J Clin Nutr 1996;50:S38–S53.
50. Simon PW. Genetic improvement of vegetable carotene content. In: Bills DD, Kung S, eds. Biotechnology and nutrition. Boston, Mass, USA: Butterworth-Heinemann, 1992:291–314.
51. Camara B, Schantz R, Moneger R. Enzymology and genetic regulation of carotenoid biosynthesis in plants. In: Bills DD, Kung S, eds. Biotechnology and nutrition. Boston, Mass, USA: Butterworth-Heinemann, 1992:301–14.
52. Rubatzky E, Yamaguchi M. World vegetables: principles, production, and nutritive values. 2nd ed. New York: Chapman & Hall, 1997.

Impact of red palm oil on human nutrition and health

David Kritchevsky

Abstract

The oil that is first obtained in harvesting the fruit of the oil palm is red because it contains carotenes, tocopherols, and tocotrienols. In the past, this fraction was separated from the palm olein and used separately. However, the presence of the palm oil tocopherol-rich fraction (TRF) is what makes red palm oil unique. Red palm oil has been shown to increase retinol levels in populations with marginal vitamin A deficiency. Red palm oil also reduces the severity of cholesterol-induced atherosclerosis in rabbits (compared with palm olein). There has been considerably more work done with TRF than with red palm oil per se. *Some authors find it to be hypocholesterolaemic, whereas others do not. Many, but not all, studies show TRF to have antitumorigenic properties as well. More data concerning the health effects of red palm oil are needed.*

Palm oil, in its original form, is red. The colour is due to the presence of tocopherols and tocotrienols. Until relatively recently these compounds have been removed and sold separately. The chemical spectrum of red palm oil is shown in table 1. The use of red palm oil *per se* in research has been rather limited. There is a more extensive literature related to the use of the tocotrienol fraction in studies of lipid metabolism, atherosclerosis, and cancer. In the ensuing discussion, the uses of red palm oil will be discussed first, and the studies in which the tocopherol fraction was used will be addressed separately. In addition to the human studies, there will be a review of the experimental studies that may be germane to human health. The nutritional aspects of palm oil have been discussed by Cottrell [1].

Manorama and Rukmini have done pioneering work in investigating the use of red palm oil as an available and inexpensive source of β-carotene and vitamin A in the human diet. They demonstrated how to make red palm oil nutritionally acceptable [2]. They also showed that 70% to 88% of the β-carotene of red palm oil is retained during cooking [2]. Twelve schoolchildren were fed a snack made with red palm oil, and a similar number were given a daily dose of vitamin A. After 60 days, the level of serum retinol was the same in both groups (table 2) [3, 4]. In a second study, children were given a snack containing either 50,000 IU of vitamin A or 4 g of red palm oil. After 30 days the serum retinol levels were the same in the two groups, and the β-carotene levels had more than trebled in the children given red palm oil (table 3). A study in children most of whom had serum retinol levels below 0.7 μmol/L found that elevations in serum retinol could be maintained one month later in probands receiving

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TABLE 1. Chemical characteristics of red palm oil

Ingredient	Content
Fatty acid (%)	
14:0	0.8
16:0	42.0
18:0	5.1
18:1	42.0
18:2	10.0
Total carotenes (μg/g)	550
β-Carotene (μg/g)	375
Tocopherols and tocotrienols (ng/L)	468

TABLE 2. Serum retinol concentrations in schoolchildren before and after supplementation with red palm oil or vitamin A

Supplement[a]	Retinol (μmol/mol)	
	Before	After
Red palm oil	0.86 ± 0.14	1.89 ± 0.23[b]
Vitamin A	0.74 ± 0.12	1.94 ± 0.21[b]

Source: ref. 3.
a. There were 12 subjects in each supplemented group.
b. Significantly different ($p < .05$).

TABLE 3. Serum retinol and β-carotene concentrations in 18 schoolchildren before and after supplementation with red palm oil or a massive dose of vitamin A for 30 days

	Retinol (μmol/L)		β-Carotene (μmol/L)	
Supplement	Before	After	Before	After
Red palm oil	0.95 ± 0.05	1.85 ± 0.08[a]	0.06 ± 0.006	0.21 ± 0.016[a]
Vitamin A	1.40 ± 0.05	1.76 ± 0.09[a]	0.07 ± 0.005	0.06 ± 0.006

Source: ref. 4.
a. Significantly different ($p < .05$).

vitamin A or 4 or 8 g of red palm oil. Six months after cessation of treatment, the retinol levels were still high in all the children given vitamin A or 8 g of red palm oil. However, the serum retinol levels had fallen below 0.7 μmol/L in one-third of the children given 4 g of red palm oil (table 4). In a recently reported study, Manorama et al. [5] supplemented the diets of healthy subjects with red palm oil and the diets of anaemic adolescent girls with red palm oil and ferrous sulphate. Inclusion of red palm oil in the diets of the 18 healthy subjects led to increases in serum retinol and α-tocopherol and decreases in serum total cholesterol and in the ratio of low-density lipoprotein (LDL) to high-density lipoprotein (HDL) cholesterol (table 5). Eighteen anaemic adolescent girls were given iron supplements (ferrous sulphate) or the same supplement with red palm oil. The haemoglobin levels were reduced by 15% in girls given the iron supplement and increased by 7% in girls given iron plus red palm oil. Van Stuijvenberg et al. [6] also found that plasma carotene levels were increased in children given biscuits made with red palm oil.

Red palm oil has also been found to improve the vitamin A status of nursing mothers and to increase the carotene content of their breastmilk [7, 8] (table 6). The human studies cited above show that red palm oil is a useful addition to the present array of dietary fats, which has the added advantage of ameliorating vitamin A deficiency. A few animal studies that have been conducted using red palm oil may serve to suggest other human uses that may have definite useful health effects.

Manorama and Rukmini [9] compared the effects of red palm oil, palm olein, and peanut oil in rats. The overall nutritional effects—feed efficiency, weight gain, fat absorption, nitrogen, calcium, and phosphorus retention—were the same for all three oils. There were no significant differences in organ weights. After 90 days, the serum cholesterol levels were similar in the three groups but the liver cholesterol levels were significantly higher in rats fed palm olein. There were no significant differences in organ weights, or in serum or liver triglycerides. Another study [10] compared the effects of red palm oil, sunflower oil, and vegetable ghee on growth and on serum and liver lipids in weanling and mature rats. In both studies the lowest serum and liver cholesterol levels were observed in the rats fed red palm oil (table 7).

The effects of red palm oil and palm olein on experimental atherosclerosis in rabbits have been compared [11]. Rabbits fed red palm oil exhibited significantly less severe atherosclerosis (table 8). These two groups were part of a more extensive study, which included a third group that was fed randomized palm oil. It was part of a series of experiments studying experimental atherosclerosis in rabbits as a function of the positional isomerism of dietary triglycerides. The positional isomerism of the fatty acids of naturally occurring triglycerides is determined genetically. Small [12] has provided data on the structure of the major triglycerides of many common fats (table 9). In our

TABLE 4. Serum retinol levels in children before supplementation, after one month of supplementation, and six months after cessation of supplementation with vitamin A or red palm oil

	Retinol (μmol/L)		
Supplement[a]	Initial	1 mo	6 mo post-supplementation
Vitamin A	0.56 ± 0.11	1.07 ± 0.25	0.90 ± 0.23
Red palm oil			
4 g	0.53 ± 0.12	1.05 ± 0.27	0.67 ± 0.10
8 g	0.60 ± 0.13	1.79 ± 0.70	0.97 ± 0.62

Source: ref. 4.
a. There were 12 subjects in each supplemented group.

TABLE 5. Mean serum lipids of 18 subjects consuming different dietary fats for 15 days

Fat consumed	Total cholesterol (mg/dl)	LDL/HDL cholesterol	Triglycerides (mg/dl)
Baseline value	195 ± 13	2.42	279 ± 24
Sunflower oil	167 ± 7	1.13	442 ± 20
Red palm oil	151 ± 5[a]	1.38	162 ± 12[a]
Ghee or butter	166 ± 10	1.62	191 ± 24

Source: ref. 5.
a. Significantly different from baseline.

TABLE 6. Retinol, α-tocopherol, and carotenes in breastmilk one month postpartum in women supplemented with sunflower oil or red palm oil

Supplement	Concentration (μg/g milk fat)			
	α-Carotene	β-Carotene	Retinol	α-Tocopherol
Control	0.12 ± 0.02	0.51 ± 0.06	14.4 ± 1.3	101.4 ± 7.0
Sunflower oil	0.13 ± 0.02	0.69 ± 0.09	14.6 ± 1.2	120.9 ± 9.5
Red palm oil	0.93 ± 0.08[a]	1.51 ± 0.12[a]	12.9 ± 1.0	87.6 ± 4.7

Source: ref. 7.
a. Significantly different from control value.

TABLE 7. Influence of red palm oil, sunflower oil, or ghee on lipid metabolism in rats

Fat (30 en %)[a]	Serum lipids			Liver lipids (mg/g)	
	Cholesterol (mg/dl)	LDL/HDL cholesterol	Triglycerides (mg/dl)	Cholesterol	Triglycerides
Red palm oil					
21 d	73.0 ± 1.5	0.52	166.0 ± 3.0	1.66 ± 0.04	23.3 ± 6.00
120 d	64.0 ± 2.1	0.85	104.0 ± 7.8	1.81 ± 0.36	24.2 ± 0.71
Sunflower oil					
21 d	100.0 ± 6.0	0.95	170.0 ± 6.9	3.20 ± 0.30	26.8 ± 6.60
120 d	84.0 ± 4.0	0.83	149.0 ± 8.9	3.04 ± 0.20	29.0 ± 0.40
Ghee					
21 d	170.0 ± 6.0	1.34	178.0 ± 0.60	3.22 ± 0.70	28.1 ± 6.90
120 d	89.0 ± 2.0	1.01	122.0 ± 1.3	3.03 ± 0.30	30.4 ± 0.13

Source: ref. 10.
a. Energy percent. There were six rats in each group.

TABLE 8. Influence of red palm oil on experimental atherosclerosis in rabbits

Supplement[a]	Serum lipids			Liver lipids			Atherosclerosis[b]	
	Cholesterol (mg/dl)	% HDL cholesterol	Triglyc-erides (mg/dl)	Total cholesterol (g/100 g)	% Ester	Triglycerides (g/100 g)	Aortic arch	Thoracic aorta
Palm olein	620 ± 36	6.8 ± 0.42	70 ± 5	1.22 ± 0.07	73 ± 1.4	0.98 ± 0.13	1.63 ± 0.23	1.31 ± 0.28
Red palm oil	769 ± 31[c]	5.5 ± 0.58	87 ± 12	1.50 ± 0.11[c]	74 ± 1.4	1.14 ± 0.18	1.00 ± 0.16[c]	1.00 ± 0.31

Source: ref. 11.
a. The rabbits (eight in each group) were fed a semipurified diet containing 0.2% cholesterol for 65 days.
b. The aortas were graded visually for atherosclerosis on a 0–4 scale.
c. Significant difference between the two supplemented groups ($p < .05$).

earlier studies, we found that saturated fat was more atherogenic for rabbits than was unsaturated fat [13] and examined the possibility that specific saturated fatty acids might exert unique atherogenic effects. We obtained specially prepared fats in which corn oil had been corandomized with trilaurin, trimyristin, tripalmitin, or tristearin to yield fats enriched in lauric, myristic, palmitic, or stearic acid. There were no differences in atherogenicity among these fats [14]. Since the randomization process had provided fats in which every component fatty acid was present to one-third of its concentration in each position of the triglyceride, we reasoned that the precise triglyceride structure might play a role in the atherogenic process.

McGandy et al. [15] fed similarly prepared fats to human subjects and after finding no specific cholesterolaemic effects, concluded that triglyceride structure could be of importance. This surmise gained credence when we realized that in the digestive process the fatty acid at the 2 position of the triglyceride is about 75% conserved [16], and thus, a specific fatty acid at the 2 position of a dietary fat could dictate the structure of the triglyceride appearing in the circulation and, in part, affect lipid metabolism. We have now

TABLE 9. Major triglycerides of some natural fats and oils[a]

Fat or oil	Major triglycerides		
Butter	PPB	PPC	POP
Lard	SPO	OPL	OPO
Tallow	POO	POP	POS
Cocoa butter	POS	SOS	SPO
Corn oil	LLL	LOL	LLP
Cottonseed oil	PLL	POL	LLL
Olive oil	OOO	OOP	OLO
Palm oil	POP	POO	POL
Peanut oil	OOL	POL	OLL
Soya bean oil	LLL	LLO	LLP
Safflower oil	LLL	LLO	LLP
Sunflower oil	LLL	OLL	LOO

Source: ref. 12.
Abbreviations: B, butyric acid; C, capric acid; L, linoleic acid; O, oleic acid; P, palmitic acid; S, stearic acid.

studied the atherogenic effects of native and randomized lard and tallow [17] and cottonseed oil [18]. The amount of palmitic acid in the 2 position influences atherogenicity but has no effect on serum cholesterol (table 10). Palm oil contains about 40% palmitic acid, but only about 3% is in the 2 position. Randomized (interesterified) palm oil also contains about 40% palmitic acid, but only 13.6% is in the 2 position. Randomized (interesterified) palm oil is significantly more atherogenic than native palm oil [11] (table 10). The mechanism underlying this effect is still unexplained.

Although studies of red palm oil have been few, there have been a number of reports of the use of the mixture of tocopherols and tocotrienols of red palm oil. It is tempting to suppose that the isolated components of red palm oil would behave like red palm oil, but that hypothesis must be put to experimental test. Qureshi et al. [19] administered a mixture of 50 mg of the tocotrienol-rich fraction (TRF) of palm oil in 250 mg palm oil to 15 hypercholesterolaemic subjects over a four-week period. The subjects took four capsules twice a day to provide 400 mg of TRF. The 40 control subjects ingested 300 mg of corn oil daily. After four weeks, the total serum cholesterol levels in the control subjects had risen slightly (2%), whereas those of the test subjects were 20% lower. The LDL cholesterol levels were virtually unchanged in the control group but had fallen by 27% in the test group (table 11). Platelet aggregation was reduced in the subjects given the TRF preparation. Triglyceride levels were slightly lower in the test patients. Tan et al. [20] also found the TRF preparation to lower plasma cholesterol in men and women. In four men whose average starting cholesterol levels were below 200 mg/dl, the average reduction was 8.2 ± 0.6%; in five men whose levels were between 201 and 239 mg/dl, the reduction was 10.6 ± 2.5%; and in 13 men whose levels were above 240 mg/dl, the reduction was 16.8 ± 2.0%. The LDL cholesterol levels fell by 10.0 ± 5.4%, 16.3 ± 2.8%, and 16.7 ± 3.2% in the three groups, respectively (table 12). The findings are not unanimous, however. Wahlqvist et al. [21] administered the TRF fraction to 44 hypercholesterolaemic subjects (23 men and 21 women) for 16 weeks. There were significant increases in serum concentrations of vitamin E, total tocopherol, and total tocotrienol, but there were no significant changes in any serum lipid fraction. They also saw no changes in plasma prostaglandins or in platelet function. Thus, this point remains to be settled.

Tomeo et al. [22] studied 50 subjects with advanced carotid stenosis. Half were given the TRF preparation in palm olein, and the controls were given palm olein. After a year, 7 patients given TRF had regression of stenosis, 2 had progression, and 16 had no change. In the control group, no patients had regression, 15 had

TABLE 10. Fat randomization and atherosclerosis

Fat	16:0%		Atherosclerosis[a]		Ref.
	Total	SN2	Aortic arch	Thoracic aorta	
Lard (N)	21.4	21.3	2.69	1.75	17
Lard (R)	21.4	7.6	1.50	0.69	17
Tallow (N)	24.8	3.8	1.29	0.79	17
Tallow (R)	24.8	8.5	1.50	0.79	17
Cottonseed oil (N)	24.0	2.0	0.58	0.13	18
Cottonseed oil (R)	23.8	8.3	1.40	0.71	18
Palm oil (N)	41.2	2.6	1.63	1.31	11
Palm oil (R)	40.4	13.6	2.13	1.81	11

Abbreviations: N, native; R, randomized.
a. The aortas were graded visually for atherosclerosis on a 0–4 scale.

TABLE 11. Serum cholesterol levels in 15 human subjects fed corn oil or Palmvitee for 28 days

Supplement	Total cholesterol (mg/dl)		LDL/HDL cholesterol	
	Baseline	28 d	Baseline	28 d
Corn oil	290 ± 31	296 ± 31	5.11	4.91
Palmvitee	294 ± 34	249 ± 27	5.30	4.48

Source: ref. 19.

TABLE 12. Influence of Palmvitee on serum cholesterol in men

Initial cholesterol (mg/dl)	*n*	Mean % reduction
<200	4	8.2 ± 0.6
201–239	5	10.6 ± 2.5
>240	13	16.8 ± 20

Source: ref. 20.

no change, and 10 had progression. The investigators saw no significant changes in serum total, HDL, or LDL cholesterol or in triglycerides (table 13). Studies of the effects of TRF on human serum lipids have, to date, yielded conflicting results, and the need for further careful clinical investigation is indicated.

The TRF of red palm oil or components of the TRF have been tested for their effects on various aspects of tumorigenesis. Ngah et al. [23] investigated the effects of tocotrienols on 2-acetyaminofluorene (AAF)-induced liver cancer in rats. They did not quantitate the severity of tumorigenesis. Microscopically assessed cell damage was reduced in tocotrienol-fed, AAF-treated rats. The activity of several pre-neoplastic marker enzymes—γ-glutamyl-transpeptidase (GGT), uridyl-diphosphate glucuronyl transferase (UDP-GT), and glutathione S-transferase (GSH-ST)—were elevated in AAF-treated rats, and the levels of the enzymes were reduced significantly in AAF-treated, tocotrienol-fed rats. The effects of palm carotenes and palm tocotrienols on the development of chemically induced skin cancer (epithelial papilloma) and virus-induced lymphoma in HRS/J hairless female mice have been reported [24]. The tocotrienol-fed mice showed delayed formation of subcutaneous lymphoma, but those fed palm carotenes showed regression in a concentration-dependent fashion. Epithelial papilloma formation was totally inhibited in groups fed 0.3% palm oil carotenes or a mixture of 0.05% each of palm oil carotenes and tocotrienols.

Palm oil carotenoids inhibited growth of dimethylhydrazine (DMH)-induced colon cancer in rats, whereas the TRF fraction enhanced tumor growth [25] (table 14). Red palm oil fortified with 1,000 ppm of carotenes inhibited growth and metastasis of human breast cancer cells (MDA-MB-435) when injected into nude mice [26]. Addition of 1,000 ppm of TRF did not influence growth or metastasis. These findings are in contrast to other reports that palm oil TRF inhibits chemically induced mammary carcinogenesis in rats [27] as well as the growth of human breast cancer cells in vitro [28–31]. Palm oil TRF appears to cause regression of epithelial tumors in BALB/c mice when added to either low- or high-fat diets [32]. Gould et al. [33] reported that neither TRF nor palm oil carotene had any effect on the growth of chemically induced mammary tumors in rats. The weight of the evidence suggests that TRF can inhibit tumor growth, but doubts have been raised and the need for further studies is indicated.

It is evident that red palm oil has definite health advantages related to serum retinol and vitamin levels in humans. Red palm oil has also been shown to be less atherogenic than palm olein in cholesterol-fed rabbits. More studies of the effects of red palm oil are needed.

TABLE 13. Change in carotid stenosis after administration of Palmvitee (antioxidant) for 12 months[a]

Change	Placebo	Antioxidant
Marked regression	0	1
Regression	0	6
No change	15	16
Progression	6	2
Marked progression	4	0

Source: ref. 22.
a. Final dosage, 240 mg tocotrienol/day.

TABLE 14. Influence of palm oil, corn oil, and tocopherol-rich fraction (TRF) on dimethylhydrazine-induced colon cancer in rats

Treatment	*n*	Mean tumor size (cm^2)	
		Colon	Duodenum
Palm oil	19	0.45 ± 0.35	0.48 ± 2.75
Palm oil + TRF	17	0.88 ± 0.61	1.93 ± 3.40
Corn oil	17	0.66 ± 0.33	0.29 ± 3.46
Corn oil + carotenoids	17	0.47 ± 0.40	0.38 ± 1.55
Corn oil + TRF	18	0.61 ± 0.37	0.66 ± 2.48

Source: ref. 25.

Studies with the TRF of palm oil are generally positive, in the sense that most of them show reduction of serum lipids and of tumor growth, but the studies are not unanimous and there have not been enough positive studies to warrant dismissal of negative findings. It is quite possible that TRF *in situ* has a greater effect than TRF supplements, as if there were synergy between TRF and palm olein. This possibility is amenable to test and should be explored.

Red palm oil has the potential to be a very useful nutrient. Presumably it will have the same effect on serum lipids and fat metabolism as palm olein, which is not hypercholesterolaemic [34, 35]. In addition, its unique content of tocopherols and tocotrienols provides an added component that has already been shown to exert beneficial effects. More studies should be done to support the growing contention that red palm oil can be a useful and healthful addition to the human diet.

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References

1. Cottrell RC. Introduction: nutritional aspects of palm oil. Am J Clin Nutr 1991;53:989S–1009S.
2. Manorama R, Rukmini C. Crude palm oil as a source of β-carotene. Nutr Res 1992;12:S223–32.
3. Rukmini C. Red palm oil to combat vitamin A deficiency in developing countries. Food Nutr Bull 1994;15:126–9.
4. Manorama R, Sarita M, Rukmini C. Red palm oil for combating vitamin A deficiency. Asia Pacific J Clin Nutr 1997;6:56–9.
5. Manorama R, Jyothermai RS, Aparna K. Effect of supplementation of red palm olein on serum lipid and antioxidant levels of healthy human subjects and iron absorption in anemic adolescent girls. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:134–46.
6. van Stuijvenberg ME, Vorster N, Faber M, Dhansay MA, Lombard CJ, Benadé AJS. The effect of a biscuit with red palm oil as a source of β-carotene on the vitamin A status of primary school children: a comparison with β-carotene from a synthetic source in a randomized controlled trial. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:156–8.
7. Lietz G, Henry CJK. Use of red palm oil for the promotion of maternal vitamin A status. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:147–54.
8. Canfield LM. Red palm oil in maternal diet improves the vitamin A status of mothers and their nursing infants. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:155.
9. Manorama R, Rukmini C. Nutritional evaluation of crude palm oil in rats. Am J Clin Nutr 1991;53:1031S–3S.
10. Sattar A, Ahmad T, Nagra SA, Hussain A. Plasma/liver lipids and lipoproteins in rats fed on red palm oil and other oils and fats. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:161–70.
11. Kritchevsky D, Tepper SA, Kuksis A. Effects of palm oil, randomized palm oil and red palm oil on experimental atherosclerosis. FASEB J 1999;13:A213.
12. Small DM. The effects of glyceride structure on absorption and metabolism. Annu Rev Nutr 1991;11:413–34.
13. Kritchevsky D, Moyer AW, Tesar WC, Logan JB, Brown RA, Davies MC, Cox HR. Effect of cholesterol vehicle in experimental atherosclerosis. Am J Physiol 1954; 178:30–2.
14. Kritchevsky D, Tepper SA. Cholesterol vehicle in experimental atherosclerosis. X. Influence of specific saturated fatty acids. Exp Mol Pathol 1967;6:394–401.
15. McGandy RB, Hegsted DM, Myers ML. Use of synthetic fats in determining effects of specific dietary fatty acids on serum lipids in man. Am J Clin Nutr 1970;23:1288–98.
16. Mattson FH, Volpenhein RA. The digestion and absorption of triglycerides. J Biol Chem 1959;239:2772–7.
17. Kritchevsky D, Tepper SA, Kuksis A, Eghtedary K, Klurfeld DM. Cholesterol vehicle in experimental atherosclerosis. 2.1. Native and randomized lard and tallow. J Nutr Biochem 1998;9:582–5.
18. Kritchevsky D, Tepper SA, Wright S, Kuksis A, Hughes TA. Cholesterol vehicle in experimental atherosclerosis. 2.0. Cottonseed oil and randomized cottonseed oil. J Nutr Biochem 1998;18:259–64.
19. Qureshi AA, Qureshi N, Weight JJK, Shen Z, Kramer G, Gapor A, Chong YH, DeWitt G, Ong ASH, Peterson DM, Bradlow BA. Lowering of serum cholesterol in hypercholesterolemic humans by tocotrienols (palmvitee). Am J Clin Nutr 1991;53:1021S–6S.
20. Tan DTS, Khor HT, Low WHS, Ali A, Gapor A. Effect of a palm-oil-vitamin E concentrate on the serum and lipoprotein lipids in humans. Am J Clin Nutr 1991;53:1027S–30S.
21. Wahlqvist ML, Krivokuca-Bogetic Z, Lo CS, Hage B, Smith R, Lukito W. Differential serum responses of tocopherols and tocotrienols during vitamin supplementation in hypercholesterolaemic individuals without change in coronary risk factors. Nutr Res 1992;12:S181–201.
22. Tomeo AC, Geller M, Watkins TR, Gapor A, Bierenbaum ML. Antioxidant effects of tocotrienols in patients with hyperlipidemia and carotid stenosis. Lipids 1995;30: 1179–83.
23. Ngah WZW, Jarien Z, San MM, Marzuki A, Top GM, Shamaan NA, Kader KA. Effect of tocotrienols on hepatocarcinogenesis induced by 2-acetylaminofluorene in rats. Am J Clin Nutr 1991;53:1076S–81S.
24. Tan B. Antitumor effects of palm carotenes and tocotrienols in HRS/J hairless female mice. Nutr Res 1992;12:S163–73.
25. Hussein F, Sundram K, Nor RM, Pathmanathan R, Wong KT. Effect of dietary palm oil and its minor components in dimethylhydrazine (DMH) induced colon cancer in rats. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:255–62.
26. Guthrie N, Carroll KK, Vandenberg T. Effect of palm oil tocotrienols and carotenoids on estrogen receptor-negative human breast cancer cells injected into nude mice. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:263–7.
27. Nesaretnam K, Khor HT, Ganeson J, Chong YH, Sundran K, Gapor A. The effect of vitamin E tocotrienols from palm oil on chemically induced carcinogenesis in female rats. Nutr Res 1992;12:879–92.
28. Guthrie N, Gapor A, Chambers AF, Carroll KK. Inhibition of proliferation of estrogen receptor-negative MDA-MB-435 and -positive MCF-7 human breast cancer cells by palm oil tocotrienols and tamoxifen, alone and in combination. J Nutr 1997;127:5445–85.
29. Guthrie N, Gapor A, Chambers AF, Carroll KK. Palm oil tocotrienols and plant flavonoids act synergistically to inhibit proliferation of estrogen receptor-negative MDA-MB-231 and -positive MCF-7 human breast cancer cells in culture. Asia Pacific J Clin Nutr 1997;6:41–5.
30. Nesaretnam K, Stephen R, Dils R, Darbre P. Tocotrienols inhibit the growth of human breast cancer cells irrespective of estrogen receptor status. Lipids 1998;33:461–9.

31. Nesaretnam K, Dorasamy S, Darbre PP. Tocotrienols inhibit growth of ZR-75-1 human breast cancer cells. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia 1999:268–81.
32. Devi S, Sekhar WY, Vincent A, Sundram K. Effect of palm oil in the regression of BALB/c epithelial tumors. Proceedings of the PORIM International Palm Oil Congress–Nutrition Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia 1999:282–90.
33. Gould MN, Haag JD, Kennan WS, Tanner MA, Elson CE. A comparison of tocopherol and tocotrienol for the chemoprevention of chemically induced rat mammary tumors. Am J Clin Nutr 1991;53:1068S–70S.
34. Hornstra G. Dietary lipids and cardiovascular disease: effects of palm oil. Oleagineux 1988;43:75–81.
35. Ng TKW, Hassan K, Lim JB, Lyc MS, Ishak B. Nonhypercholesterolemic effects of a palm-oil diet in Malaysian volunteers. Am J Clin Nutr 1991;53:1015S–20S.

Characteristics of red palm oil, a carotene- and vitamin E–rich refined oil for food uses

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Abstract

A novel process involving pretreatment of crude palm oil, followed by deacidification and deodorization using molecular distillation, can be used to produce a carotene-rich refined edible palm oil. The product is a refined red palm oil that meets standard refined edible oil specifications and retains up to 80% of the carotene and vitamin E originally present in the crude palm oil. The oil contains no less than 500 ppm carotene, 90% of which is present as α- and β-carotene. The vitamin E content is about 800 ppm, 70% of it in the form of tocotrienols (mainly as α-, β-, and γ-tocotrienols). Other valuable minor components present in this oil are ubiquinones and phytosterols. The process is also applicable for the commercial production of other natural vitamin-rich palm fractions, such as stearin, olein, and palm mid-fraction. Such products are currently available and can be used in various food applications, both as cooking media and as ingredients that enhance the appearance and nutritional value of foods.

Introduction

Crude palm oil obtained from the mesocarp of the oil palm *(Elaeis guineensis)* fruit consists mainly of glycerides and small quantities of non-glyceride components. Non-glyceride components include free fatty acids, trace metals, moisture and impurities, and minor components. The minor components in crude palm oil are carotenoids, tocopherols, tocotrienols, sterols, phospholipids, squalene, and tripterpenic and alipathic hydrocarbons [1]. The carotenoids, tocopherols, and tocotrienols are the most important of these minor components. Together, they contribute to the stability and nutritional properties of palm oil [2]. Carotenoids impart the characteristic orange-red colour to crude palm oil. They also offer some oxidative protection by themselves being oxidized first, prior to the triglycerides [1]. Carotenoids, in particular α- and β-carotene, are precursors of vitamin A that are converted into vitamin A *in vivo*. Tocopherols and tocotrienols are vitamin E isomers and are potent antioxidants that confer oxidative stability to the oil.

Some of the non-glyceride components in crude palm oil, such as free fatty acids, moisture and impurities, and trace metals, are detrimental to the stability of the oil, whereas odoriferous compounds reduce its palatability. The crude oil, therefore, needs to undergo a refining process in which the undesirable compounds are removed, thus rendering the oil more stable. Crude palm oil may undergo either physical or chemical refining, the former being the more common refining method in Malaysian palm oil refineries. These well-established processes are depicted in figure 1. Both processes involve high-temperature deodorization and deacidification under vacuum. Deodorization and deacidification in physical refining is usually carried out at temperatures of 250° to 270°C under vacuum of 3 to 5 torr, whereas chemical refining may be carried out at slightly lower temperatures of 220° to 240°C [3]. The high temperature and vacuum used during deodorization and deacidification are necessary for the removal of as much of the undesirable components as possible (free fatty acids, oxidation and decomposition products, etc.). Unfortunately, these conditions also result in the removal of some of the tocopherols and tocotrienols and the destruction of all the carotenoids present in crude palm oil. A modified physical refining process, which produces a refined palm oil of similar quality to that of refined, bleached, and deodorized (RBD) palm oil while retaining most of the carotenoids and the vitamin E originally present in crude palm oil, has been developed [4].

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

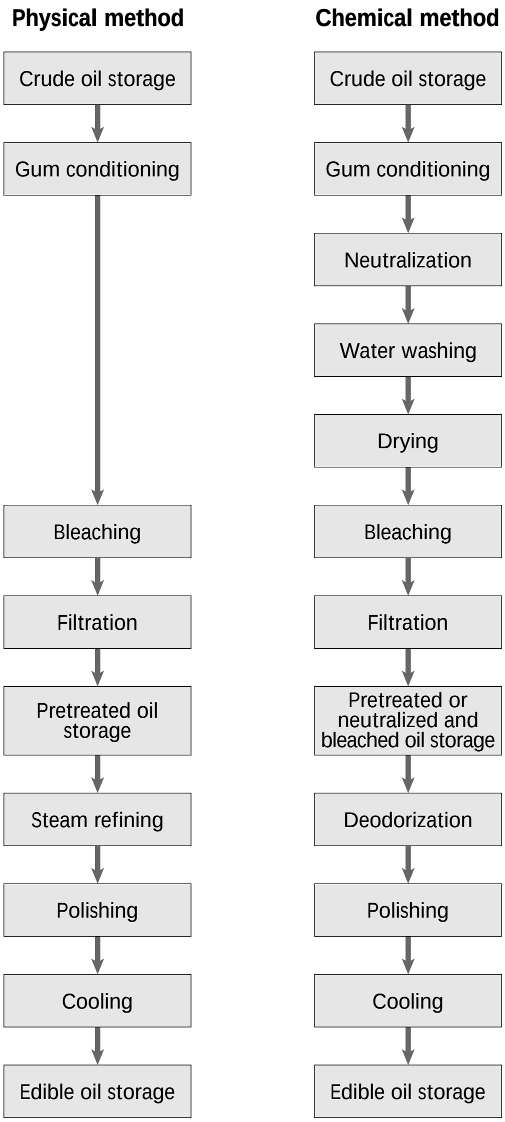

FIG. 1. Commercial refining of palm oil

Modified process

The process consists of two stages: pretreatment of crude palm oil by degumming and bleaching, followed by deodorization and deacidification by molecular distillation. The pretreatment, which removes impurities and oxidative products from crude palm oil, can be carried out in a conventional refinery. Crude palm oil is first treated with phosphoric acid, followed by treatment with bleaching earth and then filtration. The pretreated oil is then subjected to deacidification and deodorization by molecular distillation at low temperature (<170°C) and low pressure (< 100 mtorr) [5]. The quality of the product obtained through this process is comparable to that of RBD palm oil obtained by the conventional process and can meet the Palm Oil Refiners' Association of Malaysia (PORAM) quality specifications for RBD palm oil containing less than 0.1% free fatty acids and less than 0.1% moisture and impurities [6]. However, the product retains much of its red colour, since 80% of the carotenoids originally present in the crude palm oil are retained (table 1) [5]. The carotene content and quality parameters were found to be stable for nine months when the red palm oil was stored at 30°C [5] and for over one year when it was stored at 10°C [7].

In addition to the physical refining method described above, red palm oil may be obtained by a modified chemical refining route. Basically the process involves pretreatment of the crude oil followed by low-temperature deodorization [8]. In this method, pretreatment is carried out with phosphoric acid, followed by neutralization with alkali (sodium hydroxide) and water washing. The pretreated oil is then subjected to mild heat treatment under vacuum to remove moisture, oxidized materials, odours, and off-flavours.

The modified physical refining process has been patented by the Palm Oil Research Institute of Malaysia (PORIM) [4, 9]. In line with the concept of smart partnerships with the industry, the process has been commercialized through a technology transfer agreement with a Malaysian company, Global Palm Products Sdn. Bhd. The company has since started manufacturing and marketing various red palm oil fractions and products (palm oil, palm olein, palm stearin, palm mid-fractions, superolein, margarine, shortening, vanaspati, and dough fats).

Bonnie and Choo [10] studied the commercial red palm olein Carotino produced by Global Palm Products via the modified physical refining process, especially with regard to its minor components, i.e., carotenoids, vitamin E, ubiquinones, and sterols. The fatty acid composition of this product was also studied (table 2).

Carotenoids in red palm oil

Malaysian crude palm oil normally contains 500 to 700 ppm carotenoids, of which 37% is α- and 50% is β-carotene [11]. Commercially planted oil palms in Malaysia are of the *tenera* (T) variety, which is a cross between the *dura* (D) and *psifera* (P) varieties of *Elaeis guineensis.* Other oil palm species, such as *E. oleifera* [*melanococca* (M)] from South America, have been found to contain much higher levels of carotenoids, up to 4,000 ppm [11]. Carotenoids have also been reported in some crude vegetable oils, but their levels are generally much lower, usually less than 100 ppm [12]. Crude palm oil is considered the world's richest natural plant source of carotenoids. Its retinol (provitamin A)

TABLE 1. Quality characteristics of crude and red palm olein

Sample	FFA (%)	PV (mEq/kg)	Carotenes (ppm)	Vitamin E (ppm)	M&I (%)	Fe (ppm)	P (ppm)
Crude palm oil[a]	3.53	2.32	643	869	—	—	—
Pretreated palm olein[a]	3.53	0.44	514	864	—	—	—
Red palm olein[b]	0.04	0.10	513	707	0.02	1.6	n.d.
RBD palm olein[a]	0.04	0.10	Nil	561	0.03	1.6	n.d.

Source: ref. 5.
Abbreviations: FFA, free fatty acids; PV, peroxide value; M&I, moisture and impurities; n.d., not determined; RBD, refined, bleached, and deodorized.
a. Sample obtained from palm oil refinery
b. Bleached palm olein sample from refinery, processed by molecular distillation at the Palm Oil Research Institute of Malaysia (PORIM).

equivalent content has been estimated at 15 times that of carrots and 300 times that of tomatoes [13]. The carotene compositions of crude palm oil, red palm oil, and palm olein, as well as commercial red palm olein, are shown in table 3.

Although the carotene profile of crude palm oil indicates a higher content of β-carotene than of α-carotene [11], commercial red palm olein was found to contain almost equal amounts of α- and β-carotene [10]. Of these, β-carotene has the higher vitamin A activity, expressed in retinol equivalents (RE; 1 RE = 1 μg retinol = 6 μg β-carotene = 12 μg of other provitamin A carotenes). Since *in vivo* conversion of β-carotene to vitamin A is regulated by metabolic processes, the possibility of toxicity or hypervitaminosis arising from the continued consumption of red palm oil should not

TABLE 2. Fatty acid composition (%) of crude palm oil, commercial red palm olein, and red palm olein

Fatty acid	Crude palm oil	Commercial red palm olein	Red palm olein
C12:0	0.20	0.25	0.27
C14:0	1.10	1.07	1.09
C16:0	44.00	36.60	40.93
C16:1	0.10	—	—
C18:0	4.50	3.70	4.18
C18:1	39.20	46.70	41.51
C18:2	10.10	12.80	11.64
C18:3	0.40	—	0.40
C20:0	0.40	—	0.37

Source: ref. 10.

TABLE 3. Carotene composition (%) of red palm oil and red palm olein

Carotene	Palm oil		Palm olein		
	Crude palm oil[a]	Red palm oil[b]	Crude palm olein[c]	Red palm olein[c]	Commercial red palm olein[d]
Phytoene	1.3	2.0	0.9	3.6	0.61–0.68
Phytofluene	0.1	1.2	0.4	0.7	0.15–0.17
cis-β-Carotene	0.7	0.8	0.7	0.7	
β-Carotene	56.0	47.4	49.4	33.3	40.0–42.0
α-Carotene	35.1	37.0	36.9	44.2	40.6–41.9
cis-α-Carotene	2.5	6.9	5.0	7.5	9.0–11.4
ζ-Carotene	0.7	1.3	0.8	0.6	0.5–0.72
γ-Carotene	0.3	0.5	0.4	0.6	0.45–1.07
δ-Carotene	0.8	0.6	0.7	3.3	0.72–0.83
Neurosporene	0.3	Trace	—	—	0.11–0.26
β-Zeacarotene	0.7	0.5	2.1	1.6	1.17–1.33
α-Zeacarotene	0.2	0.3	0.7	—	0.50–0.56
Lycopene	1.3	1.5	1.8	3.9	0.86–1.07
Total (ppm)	673	545	643	513	665

a. Ref. 11.
b. Ref. 7.
c. Ref. 5.
d. Ref. 10.

arise. The absorption and conversion of β-carotene to vitamin A, which is metabolically regulated, also declines with increasing dietary intake [14].

The provitamin A efficacy of red palm oil has been documented by a number of investigators. Apart from this major nutritional implication, carotenoids have significant antioxidant properties. Both α- and β-carotene, as well as lycopene, are important antioxidants because of their ability to act as effective quenchers of singlet oxygen [15]. Palm carotenoids have also been suggested to have possible inhibitory effects on the development of certain types of cancer. Their role in inhibiting the proliferation of several types of cancers, such as oral, pharyngeal, lung, and stomach cancers, has been investigated. Murakoshi et al. [16] found α-carotene to be a more potent inhibitor of skin and liver cancer than β-carotene. Interestingly, the whole bouquet of palm carotenoids had a greater inhibitory effect than the isolated carotenoids. Several investigations of the possible effects of β-carotene on cardiovascular disease have had mixed results. For example, in the Physicians Health Study [17], supplementation with β-carotene had no effect on cardiovascular-related death indices over a 12-year period.

Vitamin E in red palm oil

More than 80% of the vitamin E present in crude palm oil is retained in red palm olein, compared with only about 65% in RBD palm olein (table 4). The four major types of vitamin E present are α-tocopherol, α-tocotrienol, γ-tocotrienol, and δ-tocotrienol. Their levels in crude palm oil, RBD palm olein, and commercial red palm olein are shown in table 5. Vitamin E is an important antioxidant and confers stability against oxidative deterioration of the oils. Moreover, the presence of both carotene and vitamin E provides synergistic protection against auto- and photooxidation of unsaturated triglycerides [20]. Palm tocotrienols have been reported to lower plasma cholesterol by inhibiting the activity of HMG-CoA (3-hydroxy-3-methylglutaryl coenzyme A) reductase, which regulates cholesterol synthesis in the liver [21]. Tocotrienols may also play an important role in suppressing the progression of certain types of cancer; in particular, their inhibitory effect on human breast cancer cells is encouraging [22].

Ubiquinones and sterols in red palm oil

Ubiquinones are a group of minor components found in crude palm oil. The most common is ubiquinone-10, also called coenzyme Q_{10} (CoQ_{10}). These are present at levels of 10 to 80 ppm [23–25]. Their levels are significantly lower in RBD palm olein, i.e., 10 to 20 ppm [24, 25]. Bonnie and Choo [10] found that commercial red palm olein contained 18 to 25 ppm ubiquinone-10. Although it is present at a relatively low concentration, ubiquinone-10 is important, since it has been reported to boost the immune system, relieve angina, protect against heart disease, and reduce high blood pressure [23]. The quinol form of the compound is a potent antioxidant that is 10 times more effective than vitamin E [18, 26].

Sterols are another group of valuable minor components in crude palm oil that are retained in commercial red palm olein. Their value lies in their potential application in the food and pharmaceutical industries. Phytosterols have been reported to be effective in lowering plasma cholesterol levels. Bonnie and Choo [10] found that commercial red palm olein had a higher sterol content than RBD palm oil (table 6).

Food applications of red palm oil

Sensory evaluation of red palm oil showed the product to be of good quality and acceptability, comparable to RBD palm oil [6, 28]. The product can be used in salad dressing, curries, sauces, and other dishes and gives an attractive colour to french fries [29]. It can also be used in margarine formulations to give the re-

TABLE 4. Vitamin E content in various palm oils

Sample	Vitamin E (ppm)					% Vitamin E retained
	α-T	α-T3	γ-T3	δ-T3	Total	
Crude palm olein	187	208	376	98	869	100
Red palm olein	166	202	275	64	707	81.4
RBD palm oil	139	163	205	54	561	64.6

Source: ref. 5.

TABLE 5. Vitamin E composition and content of crude palm oil, commercial red palm olein, and RBD palm olein

Sample	Vitamin E composition (%)				Vitamin E content (ppm)
	α-T	α-T3	γ-T3	δ-T3	
Crude palm oil[a]	21	24	43	11	600–1,000
Commercial red palm olein[b]	19	29	41	10	717–863
RBD palm olein[c]	25	29	36	10	515–800

a. From ref. 18.
b. From ref. 10.
c. From ref. 19.

TABLE 6. Sterol composition and content (ppm) of crude palm oil, RBD palm olein, and commercial red palm olein

Sterol	Crude palm oil[a]	RBD palm olein[a]	Commercial red palm olein[b]
Cholesterol	2.7–13	2.1–2.4	6.6–11.5
Campesterol	46.4–150	25.6–30.4	76–83
Stigmasterol	26.3–65.7	12.4–23.3	59–64
Sitosterol	120–369.5	67.6–114	187–218
Unknown	2–21	Nil–1.2	< 6
Total	210–620	109–170	325–365

a. Ref. 27.
b. Ref. 10.

quired colour to the final product and the desired level of provitamin A. It is also ideal for stir-frying, since most of the carotene is retained in the cooked food [6]. Applications of red palm oil fractions and their suitability for various products are shown in table 7.

Conclusions

The modified process involving pretreatment of crude palm oil, followed by deodorization and deacidification by molecular distillation, produces a red palm oil that meets the quality specifications of refined oils while retaining many of the minor components that are destroyed or removed in the conventional refining process. Red palm oil is a highly nutritious premium vegetable oil because of the presence of carotene, vitamin E, ubiquinones, and phytosterols. It is a versatile edible oil that can be used in various food applications. The oil can be fractionated into a number of fractions with different physico-chemical properties, thereby further extending its range of food applications.

Acknowledgements

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TABLE 7. Application of red palm oil and its fractions in various products

Product	Red palm oil	Red palm olein	Red palm stearin	Red super olein	Red palm mid-fraction
Shortenings	HS	S	HS	NS	M
Vanaspati	HS	S	HS	NS	M
Margarines	HS	S	HS	NS	M
Cooking oil (hot climate)	HS	S	NS	HS	NS
Specialty fats (for coating)	NS	NS	NS	NS	M
Ice cream	NS	S	NS	HS	NS
Cake mixes	HS	S	HS	NS	NS
Icing	S	NS	NS	NS	S
Non-dairy creamer	M	NS	S	NS	NS
Breads and biscuits	HS	S	HS	NS	HS
Salad oil	NS	S	NS	HS	NS
Salad dressing	NS	S	NS	HS	NS
Health foods	M	S	NS	HS	NS
Skin-care lotion	NS	S	NS	HS	NS

Abbreviations: HS, highly suitable; S, suitable; M, minor applications only; NS, not suitable.

References

1. Goh SH, Choo YM, Ong ASH. Minor constituents of palm oil. J Am Oil Chem Soc 1985;62:237–40.
2. Ooi CK, Choo YM, Yap CM, Ma AN. Refining of red palm oil. Elaeis 1996;8:20–8.
3. Young FVK. The refining of palm oil. PORIM Technol 1981;1:1–44.
4. Ooi CK, Choo YM, Ong ASH. Recovery of carotenoids. US Patent No. 5019668, 1991.
5. Choo YM, Ma AN, Ooi CK, Yap SC, Basiron Y. Red palm oil—a carotene rich nutritious oil. PORIM Information Series No. 11. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1993.
6. Choo YM, Ma AN, Yap SC, Ooi CK, Basiron Y. Production and applications of deacidified and deodorised red palm oil. Palm Oil Developments 1993;19:30–4.
7. Choo YM, Ma AN, Basiron Y. Red palm oil: a potential source of dietary carotenes. Malaysian Oil Science and Technology 1993;2:54–5.
8. Affandi MSY, Razali I, Rusnani M. Production of red palm oil/palm olein by modified chemical refining route. PORIM Information Series No. 37. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1995.
9. Ooi CK, Choo YM, Ong ASH. Refining of edible oil. Malaysian Patent MY-104059A, 1993.

10. Bonnie TYP, Choo YM. Valuable minor constituents of commercial red palm olein: carotenoids, vitamin E, ubiquinones and sterols. Proceedings of the 1999 PORIM International Palm Oil Congress (Chemistry and Technology). Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1999:97–108.
11. Yap SC, Choo YM, Ooi CK, Ong ASH, Goh SH. Quantitative analysis of carotenes in the oil from different palm species. Elaeis 1991;3:309–18.
12. Choo YM. Carotenoids from palm oil. Palm Oil Developments 1995;22:1–6.
13. Tan B. Palm carotenoids, tocopherols and tocotrienols. J Am Oil Chem Soc 1989;66:770–7.
14. Chandrasekharan N. Red palm oil for the prevention of vitamin A deficiency. Palm Oil Developments 1997; 27:20–4.
15. Dimascio P, Kaiser S, Sies H. Lycopene as the most efficient biological carotenoids singlet oxygen quencher. Arch Biochem Biophys 1989;274:532–8.
16. Murakoshi M, Nishino H, Satomi Y. Potent preventive action of alpha-carotene against carcinogenesis: spontaneous liver carcinogenesis and promoting stage of lung and skin carcinogenesis in mice are suppressed more effectively by alpha-carotene than by beta-carotene. Cancer Res 1992;52:6583–7.
17. Hennekens CH, Buring JE, Manson JE. Lack of effect of long-term supplementation with beta carotene on the incidence of malignant neoplasms and cardiovascular disease. N Engl J Med 1996;334:1145–9.
18. Choo YM. Antioxidants in red palm oil. Malaysian Oil Science and Technology 1996;5:15–16.
19. Gapor MTA. Effect of refining and fractionation on vitamin E in palm oil. In: Proceedings of 1989 PORIM International Palm Oil Development Conference. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1990:261–5.
20. Haila KM, Lievonen SM, Heinonen MI. Effects of lutein, annatto and γ-tocopherol on autoxidation of triglycerides. J Agric Food Chem 1996;44:2096–100.
21. Basiron Y, Sundram K. Nutritional research on palm oil and its components: the PORIM experience. Palm Oil Developments 1998;30:35–40.
22. Nesaretnam K, Guthrie N, Chambers AF, Carroll KK. Effect of tocotrienols on the growth of human breast cancer cell line in culture. Lipids 1995;30:1130–43.
23. Goh SH. Coenzyme Q. Malaysian Oil Science and Technology 1996;5:19.
24. Hazura AH. Ubiquinones in palm oil and palm oil products. Malaysian Oil Science and Technology 1996;5:18.
25. Hazura AH, Choo YM, Goh SH, Khor HT. The ubiquinones of palm oil. In: Ong ASH, Nike E, Packer L, eds. Nutrition, lipids, health and diseases. Champaign, Ill, USA: American Oil Chemists Society (AOCS) Press, 1996:122–8.
26. Choo YM, Yap SC, Ooi CK, Ma AN, Goh SH, Ong ASH. Recovered oil from palm-pressed fiber: a good source of natural carotenoids, vitamin E and sterols. J Am Oil Chem Soc 1996;73:599–602.
27. Siew WL. Palm oil sterols. Palm Oil Developments 1990;18:23–4.
28. Choo YM, Ma AN, Basiron Y. New processes for the palm-based industry. Malaysian Oil Science and Technology 1994;3:26–33.
29. Unnithan UR, Choo YM. Carotino. Red palm oil: a carotene and vitamin E rich natural product. Paper presented at Asia Edible Oil Markets '96 Conference in Singapore, 1–2 April 1996.

Nutritional potential of red palm oil for combating vitamin A deficiency

Nevin S. Scrimshaw

Abstract

Although the severe vitamin A deficiency responsible for ocular damage is now rare, subclinical vitamin A deficiency still contributes importantly to high child mortality in the developing countries of Asia. This demands urgent and effective preventive action. Although periodic large doses of vitamin A for this purpose have been a favoured approach of international agencies, the coverage achieved has been inadequate and is usually not sustainable without external support. For this reason, there has been increasing emphasis on a sustainable dietary approach to the prevention of subclinical vitamin A deficiency. One part of this can be the production and use of red palm oil as a salad and cooking oil or blended into other vegetable cooking oils. The latter will also improve the caloric density of the diets, a serious limiting factor for young children in the region. It will also add antioxidant activity to the diet.

Introduction

Severe vitamin A deficiency affects ocular tissue in two ways: by slowing the regeneration of visual pigment following exposure to bright light, and more permanently through deterioration of the epithelium of the conjunctiva and cornea. There is clear evidence that vitamin A deficiency is a serious public health problem in Asia, as listed in table 1 for a number of countries [1]. However, with a few exceptions, the problem is no longer the classical ocular manifestations of xerophthalmia and keratomalacia leading to blindness, or even the less serious Bitot's spots and night-blindness. Of greatest concern now are the more subtle effects of mild to moderate subclinical vitamin A deficiency on the resistance of young children to mortality from infectious disease.

Following a 1986 report from Aceh, Indonesia, of a 34% decrease in the mortality of pre-school children receiving periodic large oral doses of vitamin A [2], a number of other studies found decreases ranging from 20% in Ghana [3], 26% in Jumla, Nepal [4], 29% in Sarlahi, Nepal [4], 30% in Bogor, Indonesia [5], and 54% in Madurai, Tamil Nadu [6], where the vitamin A was given weekly. Studies in Hyderabad, India [7], and Sudan [8] did not report a significant effect of vitamin A supplementation on mortality.

There is no explanation for the lack of effect in Sudan, but other deficiencies may have played a role. The Hyderabad results have been questioned, because 34% of the children received only one of the two large oral doses of vitamin A called for in the 12-month study, and because the sample size was small for the much lower than expected mortality rate. UNICEF and the World Health Organization (WHO) used the Beaton meta-analysis figure of a 23% reduction in mortality with vitamin A supplementation of young children in populations in which subclinical vitamin A deficiency was prevalent [9]. However, I do not believe that averaging the figures from these eight studies is appropriate, because conditions differ in each. It can be concluded,

TABLE 1. Controlling vitamin A deficiency: programme coverage and estimated prevalence 1994–1996

South Asian country	Procurement (%) estimated coverage	Estimated clinical prevalence (%)	Estimated subclinical prevalence (%)
Afghanistan	31.0	5.2	51.0
Bangladesh	92.0	1.5	26.0
Nepal	12.4	1.0	20.6
Pakistan	4.0	0.8	17.6
India	NA[a]	0.8	17.8
Sri Lanka	2.6	0.2	7.7
Bhutan	6.2	NA	NA

a. Not applicable.

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however, that improving vitamin A nutritional status can reduce infant mortality as much as 50% under some circumstances, and with lesser effect depending on the severity of the deficiency and other unknown factors.

A study in Tanzania [10] and two in South Africa [11, 12] have shown a sharp reduction in measles mortality and other complications in children given vitamin A at the onset of measles wherever the case fatality rate exceeded 1% [13]. A single dose of vitamin A given to patients with acute shigellosis who were treated with antibiotics increased the rate of clinical cure at the end of five days from 29% to 45% [14]. Reduction in morbidity from infectious disease with improved vitamin A status has also been shown in some studies [15], including those in India [16], Thailand [17], and Congo [18], but this result seems to vary with population and locality [19]. The main effect of vitamin A deficiency seems to be on the outcome of severe infections.

There are other health benefits of preventing vitamin A deficiency in populations. It has been noted in studies in Indonesia [20] and Guatemala [21] that haemoglobin levels improve with vitamin A supplementation in populations with a high prevalence of anaemia and borderline vitamin A deficiency. A recent report from Venezuela provides evidence that this is due to a beneficial effect on iron absorption from the diet [22]. An effect on iron status and on mortality with national fortification of sugar with vitamin A was reported in Guatemala [23].

The recent report on “Progress in Controlling Vitamin A Deficiency” [1] gives not only the estimated prevalence rates for vitamin A deficiency in South Asia, but also the potential coverage based on capsule procurement. As shown in table 1, subclinical deficiency rates range from 8% in Sri Lanka and 18% in India to 51% in Afghanistan. Yet, at best, the coverage rates of periodic vitamin A supplementation programmes are only 3% to 4% in Sri Lanka and Pakistan, 12% in Nepal, and 31% in Afghanistan. No data for compliance in India were given, but it is recognized to be unsatisfactory. Only in Bangladesh is potential coverage given in this WHO tabulation as satisfactory, but past surveys that have found that its programmes miss many of the children most in need place this figure very much in doubt. Similar compliance and sustainability problems have been encountered in other regions of the world. For this reason, agencies and individuals concerned with international nutrition assistance have placed increased emphasis on dietary approaches to improve vitamin A status, particularly of young children and pregnant women, who are most at risk.

Dietary approaches

In this paper I want to emphasize the feasibility and desirability of dietary approaches to the elimination of vitamin A deficiency in developing countries in which it is a public health problem. I do not believe that the approach of giving periodic large doses of vitamin A, as is currently the principal effort in almost all countries, will ever provide adequate and sustainable coverage. The use of combined vitamin A and iron tablets given weekly may be feasible and sustainable where communities can take the responsibility for distribution and consumption. However, few countries have the community structure to manage this, and it has never been satisfactorily used.

Dietary approaches also have their difficulties. Animal food sources of preformed vitamin A are generally too costly to provide a solution to the problem until there is a substantial increase in the resources available for food purchases. Therefore, the primary effort has been to secure increased intake of vegetable sources of β-carotene and other carotenoids that are converted in the body to vitamin A. The cheapest and most available sources have been assumed to be green and yellow vegetables and some fruits.

There is considerable variation, however, in the biological availability of the β-carotene and other carotenoids in plants. Some experimental studies have shown a clear improvement in vitamin A status with increased intake of green and yellow vegetables and some fruits, but for others the practical effects have been slight. Parker, in this issue, estimates that the average bioconversion of carotene to vitamin A for humans has been overestimated by a factor of at least 10 [24]. Nevertheless, most studies reviewed found a significant improvement in vitamin A status with an increased intake of green and yellow vegetables and some fruits. In a recent example, the vitamin A status of Chinese kindergarten children who had been dewormed was sustained by supplying green and yellow vegetables in the meals served at school but decreased in those given light-coloured vegetables [25]. A further problem is the difficulty of persuading young children to eat vegetable greens. Even with much persuasion, they simply are not the favourite foods of young children.

Reaching the goal of improving vitamin A status through dietary modifications involves more than an increased intake of foods with good vitamin A activity. For example, at least 5 g per day of dietary fat is recommended in a child’s diet to optimize the absorption and utilization of preformed vitamin A and provitamin A [26]. In some field studies, a small increase in dietary fat has been effective in improving the vitamin A status of populations with very low fat intake. For such populations vitamin A or β-carotene in oil has an advantage.

Value of red palm oil

In addition to efforts to increase the consumption of carotene-containing vegetables and fruits, there is another potential dietary approach that should be pursued. The oil from the African palm is the richest known source of biologically active carotenoids. Malaysia is currently the largest source, but production is substantial in many other countries. Table 2 shows that crude palm oil has 15 times the carotene content of carrots and 44 times that of leafy vegetables. As shown in Table 3, α- and β-carotene are the principal carotenoids. Table 4 shows that the proportions of these two carotenes are similar in palm oil and carrots.

TABLE 2. Vitamin A activity of red palm oil compared with that of other plant sources

Source	RE[a]/100 g (edible portion)	Relative activity[b]
Crude palm oil	30,000	1
Carrots	2,000	15
Leafy vegetables	685	44
Apricots	250	120
Tomatoes	100	300
Bananas	30	1,000
Oranges or orange juice	8	3,750

a. Retinol equivalents.
b. No. of times below value for crude palm oil.

TABLE 3. Carotenes in crude palm oil

Carotene[a]	%
Phytoene	1.3
cis-β-Carotene	0.7
Phytofluene	0.1
β-Carotene	56
α-Carotene	35
cis-α-Carotene	2.5
ζ-Carotene	0.7
γ-Carotene	0.3
δ-Carotene	0.8
Neurosporene	0.3
β-Zeacarotene	0.7
α-Zeacarotene	0.2
Lycopene	1.3
Total (ppm)	500–700

a. Listed in the order of their elution during HPLC analysis of carotenes derived from *tenera* species.

TABLE 4. Distribution of carotenoids in carrots and crude palm oil

Carotenoid	Carrots	Crude palm oil
% of total		
α-Carotene	32	34
β-Carotene	63	60
Others	5	6
Total concentration (ppm)	< 100	500–700

Over 60 years ago, Aykroyd and Wright [27] described the value of red palm oil for the treatment of human keratomalacia. This was based on the 1920 observation of Drummon and Coward [cited in ref. 27] that the red palm oil pigment was largely carotene and possessed vitamin A activity in rats. Subsequently, Drummon et al. 1931 [cited in ref. 27] reported that the vitamin A activity of red palm oil in rats was equal to that of cod liver oil. Rosedale in 1935 [cited in ref. 27] reported that of a series of Malayan foodstuffs tested, red palm oil was by far the richest in carotene. Despite the enormous increase in the production of refined palm oil in Malaysia, Indonesia, India, and many other countries, little advantage has been taken of the nutritional potential of red palm oil. However, it has traditionally been used in foods, including some given to children in a number of Latin American and African countries.

Commercial production of refined red palm oil

Crude palm oil has a very strong taste and poor keeping qualities, but it can be refined to palatable oil that retains its red colour and provitamin A activity. Groups in India and Costa Rica have developed palatable products and demonstrated their vitamin activity. The process developed in Malaysia, shown in figure 1, economically produces a product that is palatable and retains the same high carotene content as crude palm oil. The process to produce deodorized and deacidified red palm oil involves two stages: pretreatment of the crude palm oil followed by decolourization and deodorization by molecular distillation. The product has been given the name Carotino. The way in which it differs from crude palm oil is shown in table 5. It is odourless, tasteless, and very stable, with a light red colour. Its high content of carotenoids is shown in table 6. Carotino is the

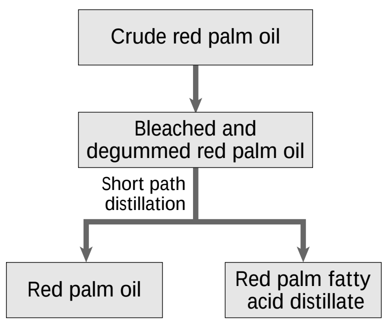

FIG. 1. Production process for red palm oil. The advantages of the process are that it can process normal crude palm oil, there is insignificant oil loss, there is no effluent problem, and most of the endogenous carotene and vitamin E are retained.

TABLE 5. Differences between crude palm oil and Carotino

Characteristic	Crude palm oil	Carotino
Free fatty acids (maximum %)	5.0	0.1
Carotenes (minimum ppm)	500	500
Vitamin E	800	800
Taste	Strong	Tasteless
Odour	Very strong	Odourless
Appearance	Semi-solid	Liquid
Stability	Very poor	Stable

TABLE 6. Carotenoid content of Carotino

Carotenoid	Content (mg/100 g)	RE[a]
α-Carotene	28,000	4,666.6
β-Carotene	17,500	1,458.3
cis-α-Carotene	0.125	10.4
γ-Carotene	0.015	1.3
β-Zeacarotene	0.035	2.9
Others	0.275	—
Total		6,139.5

a. Retinol equivalents.

most economical source of vitamin A activity compared with other vegetable sources (table 7).

Palatability and bioavailability of red palm oil

Although Carotino is currently produced commercially only in Malaysia, the process can be applied wherever there is an adequate supply of palm oil and a demand. Manorama and Rukmini [28] of the National Institute of Nutrition have shown that a palatable red palm oil product that retains its vitamin A activity can be economically prepared in India. They have also done toxicological studies in rats demonstrating the safety of repeatedly heated refined and crude red palm oil [29]. Only a small amount of red palm oil is required to supply the recommended daily allowance (RDA) of vitamin A. Manorama and Rukmini have reported that the RDA for schoolchildren could be supplied by a serving of *suji halwa* or *muruku* at a cost of 0.5 rupees, and at half this cost for pre-school children. Red palm oil can also be used in curries and in cookies and cakes [30].

There are many studies that confirm the biological availability of the carotenoids in red palm oil [31]. Schoolchildren seven to nine years of age were given either a daily dose of vitamin A or the RDA as carotene in a locally prepared red palm oil in a snack (*sujhalwa*). Figure 2 shows more than a twofold increase

TABLE 7. Cost-benefit analysis of Carotino and other sources of vitamin A

Source	RE[a]	Daily intake	Daily cost per child (US$)
Carotino red palm oil	61.39/g	6.5 g	0.0066
Existing cooking oil			0.0055
Vitamin A from red palm oil			0.0011
Tomatoes	1.00/g	400 g	0.7
Leafy vegetables	6.85/g	58 g	0.58
Carrot juice	13.33/ml	30 ml	0.212
Carrots	20/g	20 g	0.023
β-Carotene	1,000/ capsule	1 capsule	0.041
Cod liver oil	1,000/ capsule	1 capsule	0.084

a. Retinol equivalents.

in serum vitamin A in both groups [32]. When it is cooked, 70% to 88% of its carotene is retained [28]. It is advantageous to provide vitamin A activity in oil, because this also increases both caloric density and availability.

Analysis of the factors creating vitamin A deficiency has challenged some of the conventional wisdom regarding the effectiveness and practicality of depending on vegetables and fruits in the promotion of carotene-rich diets. A study in Indonesia yielded disappointing results that were attributable to the low biological availability of the carotenoids in the diets [33]. Although there are many other studies showing an improvement in vitamin A status following the controlled feeding of such foods, evidence for the effectiveness of doing so in large-scale programmes is scant. However, effective social marketing and agricultural extension achieved the widespread cultivation of the carotene-rich vine called ivy

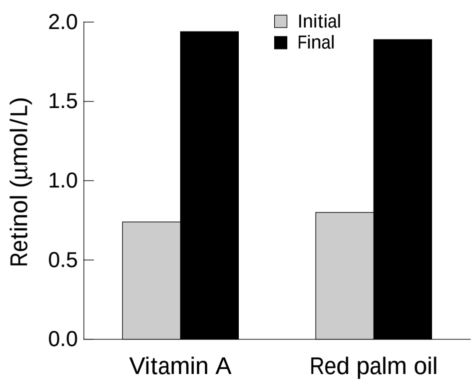

FIG. 2. Increases in serum retinol levels in schoolchildren given a dose of vitamin A or a snack containing red palm oil daily for 60 days. Source: ref. 32

gourd in a number of villages in north-east Thailand, and some improvement in vitamin A status resulted [34, 35].

The countries of South Asia have an abundance of carotene-rich fruits, such as papayas and mangoes, but these are often prohibitive in price and availability for most families. In many dietary interventions the limiting factor has proved to be cost. In some circumstances it may better to focus on an alternative food item such as red palm oil that is affordable and widely available to the population in need. Underwood suggested that this approach may have more success than horticultural activities [36]. Cooking green vegetables in red palm oil is obviously advantageous.

Infections of all kinds worsen vitamin A status, and where it is borderline precipitate clinical vitamin A deficiency. Public health interventions to reduce the burden of infections can help but cannot alone bring about impressive change in the vitamin A status of a population. They can, however, lead to incremental improvement in vitamin A nutrition and provide other health benefits. Conversely, improving vitamin A status by improving immunity can help to reduce the burden of infection.

Energy needs

When recommending any measure that increases dietary fat or changes the composition of dietary fat, two issues must be considered. One is the optimal range of total fat intake, including the amount of fat in the diet required to provide sufficient caloric density to make it possible for actively growing or physically active persons to eat enough of the diet to satisfy their energy needs. The predominantly cereal- and legume-based diets of the poor in most developing countries are bulky and of low caloric density. Rapidly growing pre-school children cannot eat enough of such a diet to meet their energy requirements, even when it is available.

In rural India only 9.5% to 15.8% of energy comes from fat, except among the highest quintile, for which the figure is 28.5% [37]. Narasinga Rao, at the 1994 Fats and Oils Congress in Kuala Lumpur, reported low dietary energy intake to be the main cause of the widespread energy deficiency among pre-school children in developing countries [38]. A minimum of 20% of calories from fat is generally considered desirable [39, 40]. Although it is also important not to exceed desirable limits from fat calories in the diet, there is little risk of this in low-income Asian populations.

Experience with palm oil as a dietary constituent

Palm oil has a long history of use as food, dating back over 5,000 years. It is used worldwide as a cooking oil in margarine and shortening and is incorporated into blended oils and a large variety of food products. Nevertheless, objections to palm oil are often encountered because it has been lumped together with coconut oil as a so-called tropical oil and both have been condemned as atherogenic. This is contrary to the very extensive evidence that when used to replace other common cooking oils, palm oil has no effect on cholesterol levels [41–45].

For example, in a Chinese study in which calories in the diet of subjects with normal cholesterol levels were replaced by a test fat, lard increased total cholesterol and low-density cholesterol, peanut oil had no effect, and palm oil caused significant decreases [25]. Like other vegetable oils, palm oil reduces cholesterol levels when substituted for coconut oil or dairy fats.

Composition of palm oil

The lipid composition of palm oil is quite different from that of other oils. Palmitic acid is the largest component of palm oil, but it contains almost as much of the monounsaturated oleic acid, the largest component of olive oil, as well as 10% linoleic acid. Moreover, palm oil has less palmitic acid in the *sn*-2 position of triglyceride than other fats in which palmitic is prominent. Kritchevsky [46] reported that the *sn*-2 position of triglycerides was most atherogenic in experimental animals. Palm oil may also contain unidentified non-glyceride compounds that lower cholesterol [47].

Unlike other common cooking oils, palm oil does not require hydrogenation for most food uses, thus avoiding the formation of *trans*-fatty acids that are known to be behave metabolically like saturated fat and are atherogenic [48, 49]. Like all vegetable oils, it contains no cholesterol.

Even refined palm oil is a rich source of vitamin E and other tocopherols and tocotrienols, but only red palm oil retains the carotene activity of the crude oil. The fortification of fats and oils for human use with preformed vitamin A is biologically effective, but blending them with carotene-rich palm oil is equally effective. Moreover, unlike synthetic vitamin A, carotene-rich palm oil is generally cheaper and can be locally produced in many countries at a favourable price. It has the further benefit of providing a broad spectrum of carotenoids [50]. However, its use should always be complemented by efforts to increase the consumption of green and yellow vegetables, not only for their vitamin A activity but also for their other essential nutrients, including protein and zinc, which enhance vitamin A absorption.

There are additional reasons for promoting red palm oil as part of the dietary approach to the control of vitamin A deficiency as a cooking oil alone or blended with another vegetable oil. These are related to its antioxidant activity, which is due not only to carotenoids but also to tocopherols and tocotrienols. There is some evidence for the protective effect of these antioxidants against coronary heart disease and possibly some forms of cancer. Vitamin E capsules are routinely recommended for persons who have evidence of coronary heart disease. Vitamin E also appears to enhance the immune system [51]. Thus the tocopherol and tocotrienol contents of red palm oil, as well as its carotenoid activity, are reasons to encourage its use.

Conclusions

Although much progress has been made in eliminating the severe vitamin A deficiency responsible for ocular damage, subclinical vitamin A deficiency still contributes importantly to the high child mortality in South Asia. This demands urgent and effective preventive actions. Although periodic large oral doses of vitamin A for this purpose have been a favoured approach of international agencies, the coverage achieved has been inadequate and its sustainability in doubt. This has led to a return to an emphasis on dietary approaches to overcoming the risk of vitamin A deficiency, particularly increased use of green and yellow vegetables and fruits. The vitamin A status of the entire population can be improved through the production and promotion of red palm oil used as a salad and cooking oil or blended into other vegetable cooking oils. The latter will also improve the caloric density of the diets, a serious limiting factor for young children. It will have the further benefit of adding antioxidant activity to the diet that may help to increase resistance to heart disease and cancer.

References

1. Micronutrient Initiative. Progress in controlling vitamin A deficiency. Ottawa, Canada: Micronutrient Initiative, 1998.
2. Sommer A, Tarwotjo I, Djunaedi E, West KP, Loeden AA, Tilden R, Mele L, and the Aceh Study Group. Impact of vitamin A supplementation on childhood mortality: a randomized controlled community trial. Lancet 1986;327:1169–73.
3. Ghana Vast Study Team. Vitamin A supplementation in northern Ghana: effects on clinical attendance, hospital admissions and child mortality. Lancet 1993;342:7–12.
4. West KP Jr, Pokhrel RP, Katz J, LeClerq SC, Khatry SK, Shrestha SR, Pradhan EK, Tielsch JM, Pandey MR, Sommer A. Efficacy of vitamin A in reducing preschool child mortality in Nepal. Lancet 1991;338:67–71.
5. Muhilal, Murdiana A, Azis I, Saidin S, Jahari AB, Karyadi D. Vitamin A–fortified monosodium glutamate and vitamin A status: a controlled field trial. Am J Clin Nutr 1988;48:1265–70.
6. Rahmathullah L, Underwood BA, Thulasiraj RD, Milton RC, Ramaswamy K, Rahmathullah R, Babu G. Reduced mortality among children in southern India receiving a small weekly dose of vitamin A. N Engl J Med 1990; 323:929–35.
7. Vijayaraghavan K, Radhaiah G, Prakasam BS, Sarma KVR, Vinodini R. Effect of massive dose vitamin A on morbidity and mortality in Indian children. Lancet 1990; 336:1342–5.
8. Herrera MG, Nestel P, El Amin A, Fawzi WW, Mohammed KA, Weld L. Vitamin A supplementation and child survival. Lancet 1992;340:267–71.
9. Beaton GH, Martorell R, Aronsdon KJ, Edmonston G, McCabe G, Ross AC, Harvey G. Effect of vitamin A supplementation in the control of young child morbidity and mortality in developing countries. ACC/SCN (Administrative Committee on Coordination/Sub-Committee on Nutrition) State-of-the-Art Series. Nutrition Policy Discussion Paper No. 13. Geneva: ACC/SCN, 1993.
10. Barclay AJG, Foster A, Sommer A. Vitamin A supplements and mortality related to measles: randomised clinical trial. BMJ 1987;294:294–6.
11. Coutsoudis A, Broughton M, Cobadia HM. Vitamin A supplementation reduces measles morbidity in young African children: a randomized, placebo-controlled–blind trial. Am J Clin Nutr 1991;54:890–5.
12. Hussey GD, Klein MA. A randomized, controlled trial of vitamin A in children with severe measles. N Engl J Med 1989;323:160–4.
13. World Health Organization. Joint WHO/UNICEF statement: vitamin A for measles. Weekly Epidemiol Record 1987;62:133–4.
14. Hossain S, Biswas R, Kabir I, Sarker S, Dibleyu M, Fuchs G, Mahlanabis D. Single dose vitamin A treatment in acute shigellosis in Bangladesh children: randomized double blind controlled trial. BMJ, 1998;316:422–6.
15. Sommer A, Katz J, Tarwotjo I. Increased risk of respiratory disease and diarrhea in children with pre-existing mild vitamin A deficiency. Am J Clin Nutr 1984;40:1090–5.
16. Milton RC, Reddy V, Naidu AN. Mild vitamin A deficiency and childhood morbidity: an Indian experience. Am J Clin Nutr 1987;46:827–9.
17. Bloem MW, Wedel M, Egger RJ. Mild vitamin A deficiency and risk of respiratory tract disease and diarrhoea in preschool and school children in northeastern Thailand. Am J Epidemiol 1990;131:332–9.
18. Donnen P, Dramaix M, Brasseur D, Birwe R, Vertongen F, Hennart P. A randomized placebo-controlled clinical trial of the effect of a single high dose or daily low doses of vitamin A on the morbidity of hospitalized, malnourished children. Am J Clin Nutr 1998;68:1254–60.
19. Editorial. Vitamin A and malnutrition/infection complex in developing countries. Lancet 1990;336:1349–51.
20. Hussaini MA. The use of fortified salt to control vitamin A deficiency. Bogor, Indonesia: Bogor Agricultural University, 1982.
21. Mejia LA, Arroyave G. The effect of vitamin A fortifi-

cation of sugar on iron metabolism in preschool children in Guatemala. Am J Clin Nutr 1983;36:87–93.
22. Layrisse M, García-Casal MN, Solano L, Barón MA, Arguello F, Llovera Layrisse D. Vitamin A reduces the inhibition of iron absorption by phytates and polyphenols. Food Nutr Bull 1998;19:3–5.
23. Arroyave G, Aguilar JR, Flores M, Guzman MA. Evaluation of sugar fortification with vitamin A at the national level. Washington, DC: Pan American Health Organization, Scientific Publication No. 384, 1979.
24. Parker RS. Methodological considerations in determining vitamin A and carotenoid bioactivity in humans. Food Nutr Bull 2000;21:124–9.
25. Zhang J, Ping W, Wang C, Shou CX, Keyou G. Nonhypercholesterolemic effects of a palm oil diet in Chinese adults. J Nutr 1997;127:509S–13S.
26. International Union of Nutritional Sciences. Statement on natural food sources of vitamin A and provitamin A. IUNS Committee Report II/6. Food Nutr Bull 1992; 14:34–5.
27. Aykroyd WR, Wright RE. Red-palm oil in the treatment of human keratomalacia. Indian J Med Res 1937;23:7–15.
28. Manorama R, Rukmini C. Effect of processing on β-carotene retention in crude palm oil and its products. Food Chem 1991;42:253–64.
29. Manorama R, Harishankar N, Polasa K, Rukmini C. Mutagenicity studies on repeatedly heated crude and refined palm oil. In: NIN Annual Report. Hyderabad, India: National Institute of Nutrition, 1989;21:29–31.
30. Manorama R, Chinnasamy N, Rukmini C. Multigenerational studies on red palm oil and on hydrogenated vegetable oil containing mahua oil. Food Chem Toxicol 1993;31:369–75.
31. Manorama R. Vitamin A supplementation through red palm oil. National workshop on red palm oil and health perspectives for India. Trivandrum, India: Regional Research Laboratory, 1997.
32. Rukmini C. Red palm oil to combat vitamin A deficiency in developing countries. Food Nutr Bull 1994;15:126–9.
33. de Pee A, West CE, Muhilal, Karyadi D, Hautvast JGAJ. Lack of improvement in vitamin A status with increased consumption of dark-green leafy vegetables. Lancet 1995;346:75–81.
34. Smitasiri S. Engaging communities in a sustainable dietary approach: a Thai perspective. Food Nutr Bull 2000; 21:149–56.
35. Wasantwisut E. Moving a health system from a medical towards a dietary approach in Thailand. Food Nutr Bull 2000;21:157–60.
36. Underwood B. Prevention of vitamin A deficiency. Working paper in prevention of micronutrient deficiencies, tools for policymakers and public health workers. Washington, DC: Institute of Medicine, 1998.
37. Bagepalli S, Narasinga Rao BS. Palm use and compatibility in India. Food Nutr Bull 1994;15:149–57.
38. Narasinga Rao BS. Low dietary fat intake as the main cause of widespread energy deficiency especially among preschool children in the developing countries. Malaysian Oil Science and Technology 1995;4:139–46.
39. Bengoa JM, Torun B, Behar M, Scrimshaw N. Metas nutricionales y guias de alimentación para America Latina: bases para su desarrollo. Caracas, Venezuela: Fundación Cavendes, 1988.
40. James WPT. The role of dietary fat in weight regulation. 22nd World Congress and Exhibition of the International Society for Fat Research. Kuala Lumpur, Malaysia: ISF, 1997:21 (abstract).
41. Gurr MI. Palm lipids: edible oils with interesting nutritional attributes. Lipid Tech 1991;3:28–30.
42. Heber D, Ashley JM, Solares ME, Wang H-J, Alfin-Slater RB. The effect of palm-oil enriched diet on plasma lipids and lipoproteins in healthy young men. Nutr Res 1992; 12:S53–9.
43. Truswell AS, Choudhury N, Roberts DCK. Double blind comparison of plasma lipids in healthy subjects eating potato crisps fried in palmolein or canola oil. Nutr Res 1992;12:S43–52.
44. Ng TKW, Hassan K, Lim JB, Lye MS, Ishak R. Nonhypercholesterolemic effects of palm-oil diet in Malaysian volunteers. Am J Clin Nutr 1991;53:1015S–20S.
45. Katan MB, Zock PL, Mensink RP. Effects of fats and fatty acids on blood lipids in humans: an overview. Am J Clin Nutr 1995; 60(Suppl):1017S–22S.
46. Kritchevsky D. Impact of red palm oil on human nutrition and health. Food Nutr Bull 2000;21:182–8.
47. Khor HT, Ng T-T, Rajendram R. The role of the nonglyceride fraction of palm oil, olive oil and corn oil in the cholesterolemic effects of these oils in laboratory animals. 22nd World Congress and Exhibition of the International Society for Fat Research. Kuala Lumpur, Malaysia: ISF, 1997:22 (abstract).
48. Mensink RPM, Katan MB. Effect of dietary *trans* fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects. N Engl J Med 1990;323:439–45.
49. Judd JT, Clevidence BA, Muesing BA, Wittes J, Sunkin ME, Podczasy JJ. Dietary *trans* fatty acids: effects on plasma lipids and lipoproteins of healthy men and women. Am J Clin Nutr 1994;59:861–8.
50. Gellenbeck KW. Carotenoids: more than just β-carotene. Asian J Clin Nutr 1998;7:272–81.
51. Scrimshaw NS, SanGiovanni JP. Synergism of nutrition, infection, and immunity: an overview. Am J Clin Nutr 1997;66:464S–77S.

Potential use of red palm oil in combating vitamin A deficiency in India

B. S. Narasinga Rao

Abstract

Vitamin A deficiency is widespread among pre-school children in India. Severe forms of vitamin A deficiency lead to nutritional blindness. Massive-dose vitamin A prophylaxis has been in operation in India since the early 1970s to prevent nutritional blindness. With a decline in the severe forms of vitamin A deficiency, the emphasis has shifted to a food-based approach to control the still widespread mild to moderate forms of vitamin A deficiency by promoting consumption of carotene-rich foods such as fruits and vegetables, especially green leafy vegetables. Compared with these sources, red palm oil is a richer source of carotenes, with 500–600 μg of carotenes per gram of oil. Further, the carotenes in red palm oil may be better absorbed than carotenes from other plant sources because they are in an oil medium,. The value of red palm oil as a rich source of carotenes to cure and prevent vitamin A deficiency was recognized and studied in India as far back as the mid-1930s. Later, during the 1980s, systematic studies in both animals and humans established the safety, acceptability, and nutritional potential of crude red palm oil as a rich source of provitamin A. During the early 1990s, community studies were carried out with edible-grade crude palm oil to improve the vitamin A status of children and mothers. With the current availability of highly refined edible-grade red palm oil, its use as a source of provitamin A at home and in feeding programmes for children should pose no problem, because it is more acceptable than crude palm oil. It can indeed prove to be a potential source of carotene to eradicate vitamin A deficiency in the country.

Introduction

Vitamin A deficiency leading to nutritional blindness has been recognized as a major nutritional problem of pre-school children in India since the early 1900s. The main cause of widespread vitamin A deficiency among the low socio-economic population in India has been attributed to their ill-balanced diets, which contain little or no vitamin A–rich food. Earlier, when synthetic vitamin A was not available, keratomalacia was treated with cod liver oil or shark liver oil. Consumption of green and yellow vegetables was also advocated as a preventive measure. During the late 1950s and early 1960s, it was estimated that nearly 40,000 pre-school children in India went blind annually from vitamin A deficiency (keratomalacia). A massive-dose vitamin A prophylaxis programme was developed and field tested by the National Institute of Nutrition, Hyderabad, during the mid-1960s. The results of this five-year study conclusively demonstrated the effectiveness of a single massive oral dose of vitamin A (300,000 IU) given annually in preventing keratomalacia among pre-school children [1, 2]. On the basis of this study, a National Programme for Preventing Nutritional Blindness was launched by the Health Ministry of the Government of India during the early 1970s, as a part of its maternal and child health programme [3]. In this programme, children are administered 200,000 IU vitamin A orally once every six months. The programme has been in operation for the past two decades all over the country. It has been evaluated by independent bodies and shown to be effective wherever it is implemented well [4].

During the late 1980s, however, nutrition surveys carried out by the National Nutrition Monitoring Bureau of the Indian Council of Medical Research, located at the National Institute of Nutrition, Hyderabad, indicated that severe forms of vitamin A deficiency leading to blindness were on the decline [5], as indicated in table 1. Consequently, since the mid-1980s the emphasis has shifted from massive-dose vitamin A prophylaxis to a dietary approach to combat vitamin A deficiency, particularly the subclinical forms that still persist widely. This approach promotes the consumption of carotene-rich foods such as green leafy vegetables and other vegetables and fruits raised in kitchen gardens [6].

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Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

During the later half of the 1980s, red palm oil, which is rich in β-carotene, was systematically studied in India as an alternative or additional source of β-carotene for combating vitamin A deficiency. Subsequently, commercial production of deodorized and deacidified crude red palm oil (DDCRPO) by the Regional Research Laboratories, Trivandrum, India [7], and a highly refined edible-grade red palm oil by the Palm Oil Research Institute of Malaysia (PORIM) [8] has given further impetus to studies on the use of red palm oil for combating vitamin A deficiency both in India and in other countries during the 1990s.

Studies on the fortification of edible oils with red palm oil as a source of provitamin A (carotene) to cure keratomalacia were initiated in India as far back as 1936 by Aykroyd and co-workers at the Nutrition Research Laboratory, Coonoor (now the National Institute of Nutrition). Unfortunately, this interesting study on red palm oil as a source of β-carotene was not followed up. The National Institute of Nutrition has, however, actively pursued other aspects of the problem of vitamin A deficiency during the subsequent decades. Studies on red palm oil as a source of provitamin A were taken up again only during the 1980s and 1990s.

TABLE 1. Change in the prevalence (%) of vitamin A deficiency in India

Year	Nutritional blindness[a]	Year	Bitot's spots[b]
		1967–69	2.7
1971–73	2.0	1975–79	1.7
1989	0.04	1989–90	0.7

a. DGHS survey.
b. National Nutrition Monitoring Board survey.

TABLE 2. Carotenes in red palm oil

Carotene	Composition (%)	Actual content (ppm)
β-Carotene	56.00	308.0
α-Carotene	35.20	193.6
cis-α-Carotene	2.49	13.7
Phytoene	1.27	7.0
Lycopene	1.30	7.2
δ-Carotene	0.83	4.6
γ-Carotene	0.33	1.8
ζ-Carotene	0.69	3.8
β-Zeacarotene	0.74	4.1
cis-β-Carotene	0.68	3.7
Neurosporene	0.29	1.6
α-Zeacarotene	0.23	1.3
Phytofluene	0.68	3.7
Total		550.0

Source: Malaysian Palm Oil Promotion Council, 1998.

Carotene content of red palm oil and its provitamin A activity (retinol equivalent)

Crude red palm oil is perhaps the richest plant source of carotene. It contains 500 to 700 ppm carotenes, the predominant one being β-carotene (table 2). All of these carotenes are destroyed during the refining of crude red palm oil to produce refined, bleached, and deodorized (RBD) palm oil. However, technologies have been developed recently to obtain deodorized and deacidified red palm oil (DDCRPO) from crude palm oil with a carotene content of 550 ppm [7]. PORIM has developed a more advanced technology to produce refined edible-grade red palm oil from crude palm oil retaining 500 ppm of carotenes [8]. Of the carotenes present in red palm oil, only α-, β-, and γ-carotenes have provitamin A activity. The β-carotene equivalents of carotenes present in red palm oil are shown in table 3. Thus, 100 μg of carotenes present in red palm oil is roughly equivalent to 80 μg of β-carotene.

Although theoretically 1 μg of pure β-carotene is equivalent to 0.5 μg of retinol, the retinol equivalence of β-carotene present in any food depends upon the efficiency of its absorption (bioavailability) from the carotene-rich foods. Although pure β-carotene is 98% absorbed, absorption of carotene from other carotene-rich plant foods has been shown by the balance method [9] to vary between 33% and 75% (table 4). The Food and Agriculture Organization/World Health Organization (FAO/WHO) assumed an absorption of only 32% and proposed a factor of 0.16 to compute the retinol

TABLE 3. β-Carotene content of red palm oil

Carotene	Content (μg/g)	β-Carotene equivalent
α-Carotene	145	80
β-Carotene	310	310
γ-Carotene	20	10
Lycopene	10	0
Xanthophyll	15	0
Total	500	400

TABLE 4. Absorption (%) of carotenes from different sources in adult subjects

Carotene source	Total carotene	β-Carotene
Pure β-carotene	—	98.0
Amaranth leaves	58.1	75.7
Papaya	45.8	90.9
Carrot	35.5	81.1
Diet with mixed carotene sources	33.4	82.0
Red palm oil	80.0	90.0

equivalent (RE) of carotenes in plant foods in its recommendation on carotene intake to meet the daily vitamin A requirement of humans [10, 11]. On the other hand, the Expert Group of the Indian Council of Medical Research has recommended a conversion factor of 0.25 to obtain the RE of carotene in plant foods [12, 13].

The bioavailability of carotenes in red palm oil can be presumed to be more than 80%, which corresponds to an RE value of 0.4, since it is a solution in oil. No attempts have been made to determine the absorption of carotenes from red palm oil in humans. However, an idea of bioavailability and RE values of carotenes from red palm oil can be obtained from experiments comparing the serum vitamin A levels of children given red palm oil or pure retinol (table 5). The two studies found that the RE value of carotenes in red palm oil was nearly 0.3. On the basis of these results, the RE value of β-carotene in red palm oil can be taken as 0.3. This conversion factor will be useful in computing the amount of red palm oil to be fed to meet the vitamin A requirement of children and adults. There is a need, however, for more systematic well-planned studies to determine directly the bioavailability of carotenes from red palm oil in humans consuming their usual diets.

Early studies on the use of red palm oil to combat vitamin A deficiency in India

In 1937 Aykroyd and Wright at the Nutrition Research Laboratory, Coonoor, considered the possibility of red palm oil as an inexpensive source of vitamin A in the tropics and the East for use both as a food and as a medicine for the treatment of vitamin A deficiency. They therefore conducted both laboratory and clinical studies in 1937 with crude palm oil from Malaya, which also formed part of the British Empire [14]. Its carotene content was spectrographically assayed at about 500 μg per gram [15].

They first tested the biological activity (provitamin A activity) of crude red palm oil in vitamin A–deficient rabbits and found that 0.5 to 2.0 ml of the oil cured the characteristic eye lesions of vitamin A deficiency in the animals. This was followed by clinical trials with crude red palm oil in collaboration with Dr. R. E. Wright at the Government Ophthalmic Hospital at Madras [14]. For easy administration of crude red palm oil, a palatable emulsion was prepared with the oil, the composition of which is given in table 6.

The emulsion containing 1.1 g of red palm oil was administered daily to one group of patients, and an emulsion containing 1.5 g of cod liver oil was administered to the control group. Both emulsions supplied the subject with over 500 IU of vitamin A. The authors

TABLE 5. Retinol equivalents (RE) of carotene from different sources

A. Based on intestinal absorption of carotene in human subjects

Carotene source	β-Carotene equivalent/μg	Absorption (%)	RE/μg
Pure β-carotene	100	98	0.50
Green leafy and other vegetables and yellow fruits	50	50	0.25
Red palm oil	80	90[a]	0.36

a. High absorption expected because red palm oil is a solution of carotene in oil.

B. Based on serum retinol response in children

Study	Vitamin A source	Amount of β-carotene/ retinol fed (μg)	Mean serum retinol increase (μg/dl)
Study 1: Daily dietary supplement of red palm oil or retinol for 2 mo	Retinol	600 μg/day	29.5
	Red palm oil	1,920 μg β-carotene equivalent/d	29.8
Study 2: Single massive dose of retinol compared with daily dietary supplement of red palm oil for 15 d; red palm oil serum retinol measured after 3 mo	Retinol	15,000 μg on d 1	9.8
		50,000 μg β-carotene equivalent fed for 15 d (8 g red palm oil/d)	9.4

TABLE 6. Composition of red palm oil emulsion

Ingredient	Amount
Red palm oil	4.7 ml
Gum ghatti (indicum)	1.69 g
Gum tragacanth	0.64 g
Cinnamon oil	0.007 ml
Peppermint oil	0.023 ml
Chloroform	0.059 ml
Glucose liquid	9.6 g
Water	To 28.35 ml

Preparation: Place the palm oil, gum ghatti, and gum tragacanth in a dry mortar. Grind to a smooth emulsion. Add the glucose and 2 drachms of water and mix to a homogeneous emulsion. Take 1 minim of cinnamon oil and 2 minim of peppermint oil and make up to 8 minim with refined spirit. Take 1 minim of chloroform and mix well.

concluded that red palm oil in the amounts administered gave results comparable to cod liver oil; that in juvenile or infantile diarrhoea, it was better tolerated than cod liver oil, which tended to aggravate the symptoms; that red palm oil emulsion was more palatable than cod liver oil emulsion; and that red palm oil was an effective substitute for cod liver oil in the routine treatment of keratomalacia.

In discussing their findings, the investigators further stated [14]:

> Clearly then, red palm oil merits attention on the part of nutrition workers in the tropics and the East. In Malaya, it has been successfully used in clinical work. In addition to being used in hospitals and dispensaries, it might be consumed as an ingredient in the diet mixed with other vegetable fats devoid of carotene. Experiments on palatability and nutritive value of mixtures of red palm oil and other fats and oils are reported elsewhere [15].

The question of introducing the palm *Elaeis guineensis* into South India is worthy of the attention of the agricultural authorities. The climate of South India would probably be suitable for its cultivation.

Incorporation of red palm oil in edible oils

When attempts were made to use crude red palm oil as a cooking oil, the foods prepared with it had a strong, unpleasant smell and taste, and the reaction of those using it was unfavourable [15]. However, when red palm oil was incorporated into commonly used vegetable oils (cooking oils) such as coconut oil, mustard oil, gingelly oil, olive oil, and cocogem at a concentration of 6% to 12%, the blend was palatable and no objectionable smell or taste was imparted to the foods, although red palm oil did impart some red colour to the oil. On the basis of this experience, a blend of the above oils containing 30 to 70 ppm of carotene, with a vitamin A potency three times that of butter, was studied for the stability of carotene during various cooking processes commonly employed in Indian homes. There was considerable loss of carotene during cooking, especially frying, which involves high heat. Even then, potato chips retained 500 to 1,000 μg of carotene per 100 g when fried in different oils containing crude red palm oil. Therefore, the blend was considered quite useful to provide adequate carotene in a daily diet.

The author concluded:

> There is no reason why the common oils or fats in the market should not be enriched with red palm oil in the manner described. The price of red palm oil in bulk appears to be of the same order as that of other common oils sold in India. Vitamin A deficiency being so common in India and rich sources of vitamin A and carotene so scarce and expensive that no feasible method of making good the deficiency should be neglected. The production of such mixtures in bulk may be suggested to commercial organizations [15].

Recommendation of the Nutrition Advisory Committee of the Indian Fund Research Association (now the Indian Council of Medical Research)

The Nutrition Advisory Committee was the national nutrition policy body, and the Indian Fund Research Association was a national organization for medical research under the British Government. After deliberation on the research on red palm oil at the Nutrition Research Laboratory, Coonoor, and the Harcourt Butler Technological Institute, Cawnpore, a strong recommendation was made for the use of red palm oil for combating vitamin A deficiency in the country and for cultivating the oil palm for the indigenous production of red palm oil.

At its third meeting in 1937, the Nutrition Advisory Committee recommended that red palm oil replace cod liver oil in the treatment of keratomalacia and that the Imperial Council of Agricultural Research should increase the cultivation of red palm oil obtained from *Elaeis guineensis* [16]. At the fourth meeting, the Nutrition Advisory Committee recommended that the vitamin A content of red palm oil be determined at the Nutrition Research Laboratory, Coonoor. Since red palm oil is cheap, it was recommended that suitable mixtures of red palm oil with other oils be explored, particularly vanaspati [16]. By the time of the fifth meeting, it was noted that refining and deodorizing red palm oil lowered its carotene content by about 50%. Studies were also done on the keeping quality of mixtures of red palm oil with other oils. The studies found that when exposed to light, these mixtures were bleached within 11 months, resulting in destruction of carotene and loss of vitamin A activity, but that the loss was less if the mixture was kept in a tin container [16].

Recent studies on red palm oil as a source of carotene to combat vitamin A deficiency in India

Studies were taken up by the National Institute of Nutrition during the 1980s. The Technology Mission on Oil was set up by the Government of India in 1983 to explore the ways and means of meeting the edible oil shortage in the country. This mission recommended, among other measures, cultivation of oil palm as a rich source of edible oil. Since palm oil was then a new source of edible oil, the National Institute of Nutrition, Hyderabad, initiated a series of animal and human studies on the nutritional effects and safety of crude red palm oil. The only source of crude palm oil in the country was a plantation at Palode in Kerala. Oil from this source was deodorized and deacidified to edible-grade crude red palm oil (deodorized and deacidified red palm oil [DDCRPO]) at the Regional Research Laboratories, Trivandrum, by a process developed there [7]. The National Institute of Nutrition carried out studies on the nutritive value of crude red palm oil in experimental animals, the safety of DDCRPO for human consumption, its use in Indian culinary practice and the acceptability of foods prepared in DDCRPO, the stability of carotenes in DDCRPO during different cooking processes, and the use of carotene in DDCRPO as a source of vitamin A during feeding trials with children.

During the 1990s, community-based studies were conducted to assess the acceptability and biological effectiveness of DDCRPO in combating vitamin A deficiency among children and mothers.

Safety evaluation of crude red palm oil

Multigenerational toxicological studies in rats showed no adverse effect of feeding crude red palm oil on growth or reproductive performance, nor were there any histopathological abnormalities [17]. Neither repeatedly heated crude red palm oil nor the foods prepared in heated crude red palm oil produced any mutagenicity according to the Ames test [18].

Stability of carotene in DDCRPO during cooking

The effect of different cooking methods traditionally employed in India on the stability of total and β-carotene in crude palm oil was studied [19]. The use of crude red palm oil in cooking processes such as baking, seasoning, and deep and shallow frying resulted in a loss of 12% to 30% of carotenes in the cooked foods (table 7). Use of the oil more than three times for deep frying resulted in complete loss of carotenes. Hence crude red palm oil can be used only for brief and wet cooking procedures that can retain about 70% of the carotenes present in the original oil. When red palm oil is used in cooked food for feeding trials, an average loss of 30% of β-carotene can be assumed.

Acceptability of foods cooked in crude red palm oil

Red palm oil blends well with Indian curries, pickles, and other yellow- or brown-coloured preparations where turmeric or kesari is added to impart a yellow colour. Trials indicated that those preparations were moderately accepted when they were made with only red palm oil, whereas preparations using a blend of red palm oil with other traditional oils at a ratio of 30:70 were well accepted. Other blends with ratios of 70:50 or 70:30 were much less accepted. Such limitations of acceptability of foods containing DDCRPO were observed in several of the community studies conducted in the Integrated Child Development Services areas. The colour and smell imparted by crude red palm oil to foods [20, 21] are the main reasons for its limited acceptability. The use of the refined red palm oil currently available may overcome some of these limitations to the acceptability of red palm oil as a cooking medium.

Studies on the effect of feeding red palm oil (DDCRPO) on the vitamin A status of children

After the safety of DDCRPO had been established and its use in Indian culinary practices investigated, the effect of DDCRPO on the vitamin A status of children was investigated to establish its usefulness in combating vitamin A deficiency.

One set of studies at the National Institute of Nutrition investigated the effect of short-term (two to three months) feeding of a food preparation incorporating

TABLE 7. Retention of total and β-carotene in cooked foods and during frying

Recipe	% retention	
	Total carotene	β-Carotene
Upma	69	70
Cake	86	88
Suji halwa	70	71
Muruku	76	77
Deep-fried food		
Before frying	100	100
1st frying	78	83
2nd frying	37	28
3rd frying	8	6

DDCRPO on the vitamin A status of children. In one study [22], 12 schoolchildren seven to nine years of age were given a sweet snack preparation made with DDCRPO that provided 2,400 µg of carotene daily for two months. An equal number of control children were given 600 µg of retinol daily. The initial and final serum retinol levels were determined in both groups. At the end of the feeding period, the liver stores of vitamin A were assessed by dehydroretinol/retinol ratios [23]. The results of this study are shown in table 8. The increase in serum retinol levels and the dehydroretinol/retinol ratios were similar in both groups, indicating that 2,400 µg of carotene (1,920 µg of β-carotene equivalent) in red palm oil was as effective as 600 µg of retinol.

In another home-based study, children were given *basen laddu* containing 4 or 8 g of DDCRPO, providing 25,000 or 50,000 µg of carotene, respectively, for 15 days. The control children were given a single massive dose of 15,000 µg of vitamin A at the beginning of the study. The serum vitamin A levels were determined at the end of one month and three months. At the end of one month, the serum vitamin A levels were similar in the control (vitamin A) group and the group given 4 g of red palm oil, and were higher in the group given 8 g of red palm oil. At the end of three months, however, the serum levels had decreased from the one-month values. The levels in the control group and the group given 8 g of red palm oil were similar, and those in the group given 4 g of red palm oil were lower [24]. The results of this study are given in tables 9 and 10.

The results of these two preliminary feeding trials clearly indicate that feeding 8 g of DDCRPO in a supplementary cooked food preparation increases serum levels of vitamin A to normal and can correct vitamin A deficiency among children of low-income groups.

Multicentre study on the use of DDCRPO in combating vitamin A deficiency in India

A multicentre study was organized under the auspices of the Nutrition Foundation of India during 1992 to 1994 to test the efficacy of red palm oil as a source of

TABLE 8. Mean serum retinol levels and dehydroretinol/retinol ratios in children before and after supplementation with red palm oil or retinol

Supplement	Amount of retinol or carotene fed daily	Serum retinol (µg/dl)			Dehydroretinol/retinol ratio		
		Initial	Final	Change	Initial	Final	Change
Retinol	600 µg vitamin A	21.2	55.6	+29.5	0.095	0.023	–0.046
Red palm oil	2,400 µg carotene	24.6	54.2	+29.8	0.073	0.225	–0.052

TABLE 9. Mean serum retinol levels in children given a single massive dose of vitamin A or red palm oil for 15 days

Group	Total dose	Serum retinol (µg/dl)		
		Initial	1 mo	3 mo
Single vitamin A dose	15,000 µg retinol	16.0	30.7	25.8
Red palm oil for 15 d				
4 g/d	25,000 µg β-carotene equivalent	15.2	30.1	19.2
8 g/d	50,000 µg β-carotene equivalent	17.2	51.3	27.8

TABLE 10. Distribution of children with serum retinol levels <20 µg/dl in different groups

Group	Total dose	Serum retinol (µg/dl)		
		Initial	1 mo	3 mo
Single vitamin A dose	15,000 µg retinol	92	0	0
Red palm oil for 15 d				
4 g/d	25,000 µg β-carotene equivalent	92	0	33
8 g/d	50,000 µg β-carotene equivalent	83	0	0

β-carotene in combating vitamin A deficiency in the community [25]. Three centres participated in this study (table 11). The study used DDCRPO prepared by the Regional Research Laboratory, Trivandrum, containing 550 ppm total carotenes, corresponding to 440 ppm β-carotene equivalents.

The daily quantity of red palm oil fed to each subject varied from 4 to 10 g. The oil was given to children at the Integrated Child Development Services centres through the supplementary feeding programmes or distributed to the mothers to be used in home-cooked foods (table 12). Acceptance was good at the Trivandrum and Coimbatore centres but poor at the New Delhi centre.

Impact evaluation

The criteria for evaluation of the impact of red palm oil on vitamin A deficiency were mainly clinical, based on eye signs such as Bitot's spots or conjunctival impression cytology. In addition to the growth of the children, morbidity and blood levels of carotenes were also assessed at some of the centres.

There was a reduction in the clinical signs of vitamin A deficiency after six months of a diet containing DDCRPO, but the results were not very impressive (table 13). Some of the limitations of impact evaluation on the basis of clinical signs are the small number of children exhibiting clinical signs at baseline, the short

TABLE 11. Multicentre community study

Centre	Community	Criteria of impact
New Delhi	Urban slum households	Conjunctival impression cytology among children
Coimbatore	Urban Integrated Child Development Services block	Clinical profile of children, pregnant and lactating women
Trivandrum	Rural community Balwadis (Kanyakumari District)	Prevalence of Bitot's spots

TABLE 12. Details of feeding of DDCRPO to test its effect on vitamin A status in the multicentre study

Centre	Daily amount of red palm oil (g)	β-Carotene[a]	Mode of feeding	*n*	Acceptability/ compliance
New Delhi	10	3,080	Incorporated into home-cooked food	64	Low (~50%)
Coimbatore					
Children	4	1,232	Supplementary food/ mid-day meal	2,425	High (~90%)
Mothers	8	2,464		681	High (~90%)
Trivandrum	5	1,540		487	High (~75%)

a. β-Carotene equivalents after correcting for 30% loss during cooking; red palm oil contained 550 ppm carotenes = 440 ppm β-carotene equivalents.

TABLE 13. Criteria for assessing the impact of red palm oil in the multicentre study

Centre	Criteria	Results
New Delhi	Conjunctival xerosis, Bitot's spots, conjunctival impression cytology (CIC), night-blindness	Significant reduction in CIC after 6 mo DDCRPO supplementation
Coimbatore	Bitot's spots, conjunctival xerosis in children fed DDCRPO; only 50% reduction in controls	Clinical signs, where present, disappeared
Trivandrum (Kanyakumari District)	Bitot's spots	No change in Bitot's spots in experimental children, increased in controls. DDCRPO protected against deterioration of eye signs

duration of the trial, and the size of the dose of β-carotene delivered in DDCRPO, which was close to the RDA and therefore may not have had any significant impact on clinical signs. The dose delivered is only adequate for the prevention of deficiency. One may have to look for the appearance of new cases with deficiency signs that would have been prevented by the dose delivered. The short-term impact can only be assessed from increases in serum vitamin A levels. Unfortunately, serum levels of vitamin A were not measured at any of the centres. Losses of carotene in the cooked food were not determined to assess the exact amount of carotene ingested daily. This type of study, in which vitamin A or β-carotene is fed at the RDA level, should be carried out for at least three years to assess its impact realistically.

According to what has been reported, there is a clear need to improve the acceptability of DDCRPO. The use of refined DDCRPO may improve acceptability considerably if it is incorporated into coloured food preparations that will mask the red colour.

Future prospects

Studies carried out so far in India have clearly established that 5 to 8 g of red palm oil given daily to children as a component of a supplementary food can improve their vitamin A status in about six months. However, these studies have certain drawbacks, such as the short duration of feeding, the small number of subjects, and poor acceptability of the food product containing the DDCRPO.

Controlled studies where children were given DDCRPO in the form of a sweet snack and where serum vitamin A levels were monitored have given unequivocal results, indicating that red palm oil is as effective as retinol in significantly improving serum vitamin A levels and bringing them into the normal range. In the community studies, where clinical improvement in vitamin A–deficient children has been used as the only criterion, the impact of DDCRPO has not been unequivocal.

In all the studies where attempts were made to provide DDCRPO to children, acceptability due to colour and odour has been a problem. This problem can be overcome with the use of highly refined red palm oil currently produced in Malaysia.

The Integrated Child Development Services scheme was introduced in India during 1975–1976, and in October 1998, 4,200 projects were operational in the entire country. These included 3,187 rural, 273 urban, and 740 tribal blocks. Currently 20.6 million children and 3.6 million mothers are covered by supplementary nutrition programmes in these projects. There is a clear need to carry out more comprehensive studies on the use of red palm oil to combat vitamin A deficiency, employing the newly developed refined DDCRPO. The operational and impact aspects should be evaluated in a few Integrated Child Development Services blocks in different regions of the country, particularly in the south and the east where vitamin A deficiency is more prevalent, by introducing about 5 g of red palm oil into the supplementary food given to children under six years of age (see Appendix).

Conclusions

Subclinical vitamin A deficiency is still widely prevalent among pre-school children in India, although the incidence of clinical forms of vitamin A deficiency is on the decline. Available resources of β-carotene, such as vegetables and fruits, are not adequate to meet the country's requirements. Alternative or additional β-carotene sources such as red palm oil are to be explored to combat vitamin A deficiency. Red palm oil is the richest dietary source of β-carotene, containing 500 ppm total carotene (400 ppm β-carotene equivalents) with high bioavailability; the RE value is 0.3 μg/μg. Crude red palm oil as a source of vitamin A was studied in India as far back as 1936–1938 for treatment of vitamin A–deficient children and for fortification of edible oil with β-carotene. Its use as a source of vitamin A was then strongly recommended. More systematic studies on red palm oil were carried out during the 1980s and 1990s to establish its potential as a vitamin A source to improve the vitamin A status of children by increasing serum vitamin A levels and by preventing symptoms of vitamin A deficiency. Red palm oil is thus a potential source of vitamin A for combating widespread vitamin A deficiency among children in India. The most effective way to deliver red palm oil to vitamin A–deficient children is to incorporate it into the supplementary food supplied to children under six years of age and their mothers under the Integrated Child Development Services. Integrated Child Development Services is currently operative in 80% of all administrative blocks in the country and covers 20.6 million children and 3.8 million mothers of low-income families in rural, urban, and tribal areas. Multicentric pilot operational studies to introduce red palm oil into the Integrated Child Development Services supplementary feeding programme and to test its efficacy in preventing vitamin A deficiency among children are proposed.

Appendix
Proposed evaluation of red palm oil in the Integrated Child Development Services programme in India

The following are the highlights of a proposed project to study the feasibility of introducing red palm oil into the Integrated Child Development Services supplementary feeding programme to improve the vitamin A status of children of low socio-economic groups.

1. The first phase of the study would test the operational feasibility of providing red palm oil routinely through the supplementary food given to children and mothers. The red palm oil should be introduced in each block where different type of foods are used in the feeding programmes. In this part of the study, the acceptability of red palm oil should be evaluated. Integrated Child Development Services workers should be educated and trained about red palm oil, its beneficial effects, and its use in the feeding programme.
2. The second phase of the study would introduce red palm oil in a few blocks in different regions of the country, and its impact on vitamin A status of children would be monitored over a period of three years or more.
3. The monitoring criteria should include disappearance of ocular signs of vitamin A deficiency; absence of new cases with ocular signs, particularly in the younger age groups; wherever possible, serum vitamin A levels concurrently or in a subsample of the cohort; and morbidity. Growth is already monitored as a part of the Integrated Child Development Services programme.
4. By introducing 5 g of red palm oil into the supplementary food, the amount of food given can be reduced by an amount corresponding to 40 kcal (~10 g to 12 g of cereals per child), since 5 g of red palm oil provides 40 kcal.
5. Wherever processed or ready-to-eat foods are in use, the technology of introducing red palm oil into the processed food should be developed; the stability of carotene in the food during manufacture, storage, and distribution should be assessed; and appropriate overages should be added to make good any loss of carotene.

Once the second phase is over, the concerned authorities should make a decision on the introduction of red palm oil into the Integrated Child Development Services supplementary feeding programme on a permanent basis. For this kind of large-scale operation, a regular supply of good-quality red palm oil should be ensured. Nearly 30,000 to 40,000 tons of red palm oil would be needed annually to cover 20 million children.

References

1. Swaminathan MC, Susheela TP, Thimmayamma BVS. Field prophylactic trial with a single annual oral massive dose of vitamin A. Am J Clin Nutr 1970;23:119–22.
2. Vijayaraghavan K, Rao NP, Sarma KVR, Reddy V. Impact of massive dose of vitamin A on incidence of nutritional blindness. Lancet 1984;2:149–51.
3. Government of India. Policy on Management of Vitamin A Deficiency, Ministry of Health and Family Welfare, Government of India, New Delhi.
4. Vijayaraghavan K, Rao NP. An evaluation of the National Prophylaxis Programme against blindness due to vitamin A deficiency. Nutr Rep Int 1982;25:431–.
5. National Nutrition Monitoring Bureau. Report for 1975–77 and 1989–90. Hyderabad, India: National Institute of Nutrition, Indian Council of Medical Research, 1975–77 and 1989–90.
6. Vijayaraghavan K. Horticultural intervention for nutrition improvement. In: Combating vitamin A deficiency through dietary improvement. In: Gopalan C, Rao BSN, Seshadri S, eds. Special Publication Series 6. New Delhi: Nutrition Foundation of India, 1992:167–.
7. Armughan C, Sundaresan A, Jayalakshmy A. Red palm oil production: perspective for India. In: Armughan et al., Proceedings of a national workshop on red palm oil for health. Perspectives for India. Trivandrum: RRL: 1997:11–.
8. Affandi MSY, Razali I, Rusnani M. Production of red palm oil by modified chemical refining route. PORIM Information Series No. 37. Kuala Lumpur, Malaysia: Palm Oil Research Institute of Malaysia, 1995.
9. Nageswara Rao C, Narasinga Rao BS. Absorption of dietary carotene in human subjects. Am J Clin Nutr 1970; 23:105–9.
10. Report of a Joint FAO/WHO Expert Group. Requirement of vitamin A, thiamine, riboflavin and niacin. WHO Technical Report Series No. 362. Geneva: World Health Organization, 1967.
11. FAO. Requirement of vitamin A, iron, folate and vitamin B_{12}. Report of a joint FAO/WHO expert consultative group. Rome: Food and Agriculture Organization, 1988.
12. Gopalan C, Narasinga Rao BS. Dietary allowances for Indians. Special Report Series No. 60. New Delhi: Indian Council of Medical Research, 1990.
13. Indian Council of Medical Research. Nutrient requirements and recommended dietary allowances for Indians. Report of an expert group. New Delhi: Indian Council of Medical Research, 1990.
14. Aykroyd WR, Wright RE. Red palm oil in the treatment of human keratomalacia. Indian J Med Res 1937;26:7–10.
15. De NK. The possible use of red palm oil in supplementing the vitamin A activity of common vegetable oils. Indian J Med Res 1937;26:11–15.

16. Nutrition Advisory Committee. Indian Research Fund Association Reports of 3rd, 4th and 6th Meetings. Hyderabad: Indian Research Fund Association, 1937, 1938, 1940.
17. Manorama R, Rukmini C. Nutritional evaluation of crude palm oil in rats. Am J Clin Nutr 1991;32 (Suppl): 1021S–33S.
18. Manorama R, Harishankar N, Polasa K, Rukmini C. Mutagenic studies on repeatedly heated crude and refined palm oil. J Oil Technol Assoc India 1989;21:29–31.
19. Manorama R, Rukmini C. Effect of processing on β-carotene retention in crude palm oil and its products. Food Chem 1991;42:253–64.
20. Nayar O, Sharma TD, Yadav R, Kapil U. Assessment of acceptability of foods prepared by deodorized and deacidified palm oil in a national programme. New Delhi: All India Institute of Medical Sciences, 1996.
21. Khader V, Aruna K, Nirmala Devi G, Nirmalamma. A report of the study on the operational feasibility of introducing red palm oil into supplementary feeding programme in urban ICDS Centres. Hyderabad: Acharya NG Ranga Agricultural University, Rajendrangar, 1996.
22. Manorama R, Brahmam GNV, Rukmini C. Red palm oil as a source of β-carotene for combating vitamin A deficiency. Plant Foods Hum Nutr 1996;49:75–82.
23. Tanuinihardjo SA, Muhidal YY, Peraesih D, Sulaiman Z, Karyadi D, Olson JA. Vitamin A status in preschool age Indonesian children as assessed by the modified relative dose response assay. Am J Clin Nutr 1990;52:1068–72.
24. Sarita Mohapatra, Manorama R. The protective effect of red palm oil in comparison with massive vitamin A dose in combating vitamin A deficiency in Orissa, India. Asia Pacific J Clin Nutr 1997;6:246–50.
25. Nutrition Foundation of India. Use of carotene rich foods to combat vitamin A deficiency in India. A multicentric study. Part II. In: Seshadri S, ed. Studies on red palm oil. NFI Scientific Report No. 12. New Delhi: Nutrition Foundation of India, 1996:114–39.

South African experience with the use of red palm oil to improve the vitamin A status of primary schoolchildren

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Abstract

A randomized, controlled, three-month trial compared the effect of biscuits containing red palm oil as a source of β-carotene and biscuits containing synthetic β-carotene on the vitamin A status of primary schoolchildren. Children consuming either type of fortified biscuit had a significant improvement in serum retinol concentrations compared with control children who received an unfortified biscuit. Using a red palm oil shortening in the biscuit has several other advantages. Unlike the commercial fat normally used in the baking industry, red palm oil contains no trans *fatty acids. Because of its high carotenoid and vitamin E contents, the need to add synthetic β-carotene and antioxidant to the baking mix is eliminated. Quality control is simplified. Production costs for the red palm oil biscuit are slightly lower than those for the synthetic β-carotene biscuit. Red palm oil is thus ideally suited for use as a source of β-carotene in food fortification in the baking industry.*

Introduction

Micronutrient deficiencies are prevalent in developing countries worldwide. Four main strategies to combat micronutrient deficiencies were identified at the International Conference on Nutrition in Rome in 1992: dietary diversification, micronutrient supplementation, food fortification, and nutrition education. The food-based approach, of which fortification is one, is the most sustainable and offers a solution in both the medium and the long term.

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A micronutrient-fortified biscuit in school feeding

A recent study by the Nutritional Intervention Programme of the Medical Research Council in South Africa showed that a biscuit can be used successfully as a vehicle for fortification in primary school feeding [1]. The micronutrient status of 115 schoolchildren (aged 6–11 years) from a poor rural community was assessed before and after consumption of a biscuit fortified with β-carotene, iron, and iodine for a period of 12 months and compared with that of a control group of 113 children who consumed a non-fortified biscuit. The biscuits were distributed daily during the school week; distribution and consumption were closely supervised, and compliance and the reason for absence were monitored and recorded daily. To exclude parasitic infection as a confounding factor, all children were dewormed before the intervention and at 4-month intervals for the duration of the study. The 12-month intervention resulted in a significant improvement in vitamin A, iron, and iodine status. Table 1 summarizes the vitamin A status of the children before and after 12 months of intervention. Morbidity from respiratory and diarrhoea-

TABLE 1. Serum retinol in primary school children before and after 12 months of intervention with a micronutrient-fortified biscuit providing 2.1 mg of synthetic β-carotene per day

	Retinol (µg/dl)	
Measurement	Control group (n = 113)	Intervention group (n = 115)
Baseline	21.6 (5.7)[a] [40.7%][b]	22.1 (5.2) [39.1%]
12 mo	21.7 (5.5) [42.5%]	26.2 (6.2) [12.2%][c,d]

Source: ref. 1.
a. Mean (SD).
b. [percentage of children with serum retinol < 20 µg/dl].
c. p < .0001 compared with baseline (Wilcoxon signed-ranks test for paired data).
d. p < .0001 compared with change in control group (Wilcoxon two-sample test).

related diseases and cognitive function also appeared to have been favourably affected. The study concluded that a micronutrient-fortified biscuit in school feeding is a feasible, practical, and effective way of improving the micronutrient status of primary schoolchildren.

A major advantage of using a biscuit as a vehicle for fortification in school feeding is that is considered a snack rather than a meal and is therefore unlikely to replace meals given to the child at home; additional advantages are that it needs no preparation, is easy to distribute, has a long shelf-life, and can easily be monitored.

Red palm oil as a source of β-carotene in the biscuit

A commercial hydrogenated marine oil normally used in the baking industry was used as a shortening (baking fat) in the biscuit. This fat contains *trans* fatty acids, and because of the untoward effects of *trans* fatty acids on plasma lipids and lipoproteins [2], its use in long-term feeding programmes can be questioned. Alternative sources of fat were therefore considered. The Medical Research Council subsequently approached Global Palm Products Sdn. Bhd. (Johor Darul Takzim, Malaysia) for a baking fat derived from refined red palm oil. Because palm oil has a moderate level of saturation, it does not require hydrogenation for use as a fat component in foods and is thus free of *trans* fatty acids. Red palm oil is also a rich natural source of carotenoids (500–700 ppm), of which approximately 50% is β-carotene. Furthermore, it also contains tocopherols and tocotrienols (about 1,000 ppm), which have powerful antioxidant properties. If red palm oil is used in the biscuit instead of the usual commercial fat, not only will the biscuit be free of *trans* fatty acids, but the need to add synthetic β-carotene and a synthetic antioxidant to the biscuit will also be eliminated. Quality control with regard to fortification will concomitantly be simplified. The advantages of substituting hydrogenated marine oil with red palm oil shortening are summarized in table 2. The biscuit contains 17% fat, which makes the inclusion of red palm oil–based shortening in the biscuit a viable option. Results from a previous study [3] showed that red palm oil can be incorporated in a biscuit and that the end product was well accepted by schoolchildren with regard to taste and appearance; compliance in this study was more than 80%, and 98% of the children said that they liked the taste of the biscuit.

The objective of the follow-up study was to replace the hydrogenated marine oil in the previous biscuit with red palm oil and evaluate its effect on the vitamin A status of primary schoolchildren in a randomized, controlled trial. A biscuit with β-carotene from a synthetic source was included for purposes of comparison. Four hundred 5- to 11-year-old children from two neighbouring primary schools in the same area where there is a similar prevalence of subclinical vitamin A deficiency (56% of children with serum retinol < 20 mg/dl) were randomly assigned to one of three groups: a group receiving a placebo biscuit, a group receiving a biscuit with synthetic β-carotene as a vitamin A fortificant (and a synthetic antioxidant), and a group receiving a biscuit with refined red palm oil as a source of β-carotene and as a source of antioxidants (tocopherol and tocotrienols). The synthetic β-carotene and red palm oil biscuits were designed to provide 34% of the recommended dietary allowance (assuming a conversion factor of β-carotene to retinol of 6:1) [4]. Vitamin A status was assessed before and after three months of intervention.

After the three months of intervention, a significant improvement in serum retinol concentrations was seen in both the group receiving synthetic β-carotene and the group receiving red palm oil as compared with the control group (table 3). Studies in India showed improved vitamin A status in children at risk for vitamin A deficiency who were given red palm oil [5]. Our results showed that a red palm oil–based shortening used in a biscuit effectively raised serum retinol concentrations. The study will be extended for another three months. The production cost for the red palm oil biscuit was US$4.6 per child per school year, slightly lower than the cost of the biscuit in which synthetic β-carotene was used as a vitamin A fortificant (table 4). At a current suggested retail price of about US$1/kg, the estimated cost per child per day will be US$0.045, providing 10% of the daily energy and 34% of the daily β-carotene requirements. This biscuit has now been commercialized and is available on the South African market.

TABLE 2. Differences between biscuits with commercial shortening and biscuits with red palm oil–based shortening

Biscuit baked with commercial shortening	Biscuit baked with red palm oil–based shortening
Contains *trans* fatty acids	No *trans* fatty acids
Synthetic β-carotene	Natural source of β-carotene
No other carotenoids	Contains other carotenoids
Synthetic antioxidant	Contains antioxidant vitamin E constituents (tocopherols and tocotrienols)
Quality control tedious	Quality control simplified
Cumbersome to add β-carotene and antioxidant to baking mix	Red palm oil–based shortening naturally contains β-carotene and antioxidant

TABLE 3. Serum retinol (mg/dl) in primary schoolchildren before and after three months of intervention with biscuits fortified with synthetic β-carotene or red palm oil biscuit

Measurement	Control biscuit (n = 137)	β-Carotene-fortified biscuit (n = 130)	Red palm oil biscuit (n = 133)
Baseline	20.6 (5.8)[a] [17.5%][b]	20.4 (6.0) [17.7%]	20.8 (7.0) [15.8%]
3 mo	21.6 (5.9) [13.1 %]	24.4 (5.6) [4.6%][c]	24.0 (6.7) [6.8%][c]

a. Mean (SD).
b. [percentage of children with low serum retinol levels] using a cut-off of < 15 mg/dl.
c. $p < .005$ compared with change in control group (ANOVA).

Conclusions

A biscuit baked with a refined red palm oil shortening, containing approximately 400 ppm total carotenoids, is as effective as a biscuit with synthetic β-carotene as a vitamin A fortificant in addressing marginal vitamin A deficiency in schoolchildren. In addition, the use of a red palm oil–based shortening has several other advantages that render it ideally suited for food fortification in the baking industry. The process is simple, easy to monitor, and cost-effective, and it can be used for mass supplementary feeding programmes in areas where vitamin A deficiencies are known to occur. The product has a shelf-life of approximately six months and is ideally suited for use in remote areas.

TABLE 4. Comparison of production costs per child of the three different biscuits[a]

Period	Unfortified biscuit	Synthetic β-carotene biscuit	Red palm oil biscuit
Per day (SA cent)	13.3	15.1	13.8
Per school year (SA Rand)	26.56	30.24	27.68
Per school year (US$)	4.4	5.0	4.6

a. The suggested retail price is ± R6/kg (1US$/kg) for both the synthetic β-carotene and the red palm oil biscuits.

References

1. van Stuijvenberg ME, Kvalsvig JD, Faber M, Kruger M, Kenoyer DG, Benadé AJS. The effect of an iron, iodine and β-carotene fortified biscuit on the micronutrient status of primary school children: a randomized controlled trial. Am J Clin Nutr 1999;69:497–503.
2. Judd JT, Clevidence BA, Muesing RA, Wittes J, Sunkin ME, Podczasy JJ. Dietary *trans* fatty acids: effects on plasma lipids and lipoproteins of healthy men and women. Am J Clin Nutr 1994;59:861–8.
3. van Stuijvenberg ME, Vorster N, Faber M, Dhansay MA, Lombard CJ, Benadé AJS. The effect of a biscuit with red palm oil as a source of β-carotene on the vitamin A status of primary school children: comparison with β-carotene from a synthetic source in a randomised controlled trial. Proceedings of the PORIM International Palm Oil Congress, 1-6 February 1999, Kuala Lumpur, Malaysia. Kuala Lumpur: Palm Oil Research Institute of Malaysia, 1999:156–8.
4. National Research Council. Recommended dietary allowances. 10th ed. Washington, DC: National Academy Press, 1989.
5. Manorama R, Sarita M, Rukmini C. Red palm oil for combatting vitamin A deficiency. Asia Pacific J Clin Nutr 1997;6:56–9.

Use of red palm oil for the promotion of maternal vitamin A status

G. Lietz, C. J. K. Henry, G. Mulokozi, J. Mugyabuso, A. Ballart, G. Ndossi, W. Lorri, and A. Tomkins

Abstract

Ninety rural Tanzanian women were recruited during the last three months of pregnancy and divided into three study groups: a control group given dietary advice to promote intake of dark-green leafy vegetables, a group given dietary advice plus sunflower oil, and a group given dietary advice plus red palm oil. Supplementing pregnant women with red palm oil, which is rich in provitamin A, increased their plasma and breastmilk concentrations of α- and β-carotene significantly, whereas women given sunflower oil had significantly higher amounts of α-tocopherol in their plasma and breastmilk than the control group. Moreover, the consumption of either red palm oil or sunflower oil retarded the decline in the concentration of retinol in breastmilk as seen in the control group during the progression of lactation. This indicates that the consumption of an oil rich in α- and β-carotene or α-tocopherol promotes retinol levels in breastmilk.

Introduction

For the last three decades, vitamin A deficiency has been recognized as a major public health problem in the developing world. Vitamin A is required for normal foetal development during pregnancy [1, 2] and for the infant's metabolic requirements and accumulation of stores of the vitamin during lactation [3]. Subclinical vitamin A deficiency has been observed in breastfed infants [4], suggesting that lactating women in these countries may have insufficient vitamin A stores. Nevertheless, breastmilk is still the best dietary source of vitamin A in early and later infancy, and it protects the infant against infectious diseases. Infections may deplete vitamin A stores and can precipitate xerophthalmia if the stores are very low. Thus, breastfeeding provides significant protection against xerophthalmia [5, 6]. However, a breastmilk vitamin A concentration of 1 µmol/L is only just sufficient to meet the infant's metabolic requirements, without permitting accumulation of stores of the vitamin [3]. If maternal vitamin A status is poor, breastfed infants are likely to be subclinically vitamin A deficient by six months of age.

Supplementation of women with vitamin A or β-carotene capsules has been shown to markedly decrease pregnancy-related mortality and the incidence of night-blindness during pregnancy and lactation [7]. High-dose supplementation of vitamin A soon after delivery has been used as an intervention strategy [8]. However, this practice may not be practical and sustainable in rural situations where home deliveries occur. An alternative approach to the administration of vitamin A capsules to pregnant and lactating women is a food-based intervention. Food-based interventions promote and encourage the consumption of foods that are naturally rich in micronutrients and appear to be a promising and sustainable approach to enhance the vitamin A status of pregnant and lactating women in the developing world.

Few studies have simultaneously explored the relationship between β-carotene intake in lactating women and the concentration of carotenoids in milk and serum [9]. In the present study we therefore used red palm oil, one of the richest sources of carotene, to improve maternal vitamin A and antioxidant status. The experimental design was such that the women were allocated to one of three food-based interventions. Subjects were allocated to three groups with access to dietary advice on increased consumption of dark-green leafy vegetables (control group), dietary advice plus sunflower oil, and dietary advice plus red palm oil.

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Subjects and methods

Materials

Red palm oil was provided by the Palm Oil Research Institute of Malaysia (PORIM), and sunflower oil was bought locally in the study area from a retailer. All reagents and adsorbents were of analytical grade and were purchased from Merck, Lutterworth, UK, or Sigma Chemicals, Poole, UK.

Collection and preparation of samples

Venous blood samples were collected at recruitment and at one and three months postpartum by venipuncture and placed on ice until separation in the base laboratory in Singida, Tanzania. After separation, plasma samples were stored at –20°C until analysis. Spot milk samples were collected at one and three months from both breasts by manual expression before and after the infants were fed on each breast. Attempts were made to collect equal amounts from each breast, which were then pooled. Milk samples were put on ice and stored at –20°C as soon as they got to the base laboratory in Singida. The samples were analysed within six months of collection. Milk and plasma carotenoids and tocopherols were measured by high-performance liquid chromatography (HPLC).

Subjects

Ninety pregnant women in their third trimester were recruited from three different villages in Ilongero Division, Singida Rural District, Tanzania. Mothers were recruited from the villages by word of mouth among nursing and health-care workers. They were divided into three equal study groups allocated to one of the three food-based interventions.

A research nurse and an agricultural division officer were recruited to ensure close supervision of the project. Cooking demonstrations were performed during recruitment using either sunflower seed oil or red palm oil. Women were encouraged not to heat the oil for too long and to incorporate the oil into local recipes containing leaves that were rich in provitamin A. Instructions were given to use the oil for the whole family, and women were instructed to use four tablespoons (~12 g) of oil for themselves per day, and pro rata for their husbands and children. Adequate oil was provided to the household to ensure that the whole family would benefit from the treatment for the duration of the six-month feeding trial. The red palm oil obtained from PORIM had a known quantity of carotenoids, which was specified by the manufacturers and confirmed at the Tanzania Food and Nutrition Centre laboratory in Dar-es-Salaam.

Blood samples of 5 ml each were taken at baseline, and breastmilk samples of 25 ml were taken at one and three months postpartum. Haemoglobin was measured at these sampling dates and was used as an exclusion criterion at baseline. Severely anaemic women (haemoglobin < 7 g/dl) and women with severe clinical infection were excluded. Similarly, those who were unwilling or unable to enter the study and to use the dietary promotion techniques proposed were excluded.

To ensure that all women in the study had normal antenatal care medicines, the project provided daily haematinics (ferrous sulphate and folic acid tablets), deworming supplies (one dose of mebendazole), and weekly prophylactic malaria treatment (chloroquine sulphate) throughout pregnancy.

Ethical issues and considerations

The study was approved by the Research and Ethics Committee of the Tanzania Food and Nutrition Centre. All women had the study explained to them, and it was made clear that they were under no compulsion to enter or continue in the study.

Results and discussion

The results showed that supplementing pregnant women with provitamin A–rich red palm oil increases α- and β-carotene concentrations significantly in plasma and breastmilk (figs. 1 and 2). Despite the achievement of very high levels of carotene in both plasma and breastmilk, the consumption of red palm oil did not increase retinol levels. However, the subjects who received red palm oil had high levels of retinol in their plasma (1.17 μmol/L) and milk (1.36 μmol/L) at the end of the study, comparable to the end-point retinol levels of the subjects receiving enriched wafers in the study of de Pee et al. (1.16 and 1.47 μmol/L, respectively) [10].

Since supplementation did not lead to significant increases in milk retinol in the women given red palm oil, an earlier start of supplementation or higher doses of β-carotene might have yielded a different outcome. On the other hand, breastmilk retinol responded slowly to daily β-carotene supplementation in a study conducted in Bangladesh [11], with significantly elevated values only at nine months postpartum. Therefore, differences between the red palm oil and the control groups in the present study might have occurred at a later stage of lactation.

In our study the consumption of red palm oil or sunflower oil retarded the well-described decline in the concentration of retinol in breastmilk during the progression of lactation [12] (table 1). This suggests that the consumption of an oil rich in α- and β-carotene or α-tocopherol seems to conserve retinol concentration in breastmilk, which in the long term will be beneficial to the infant.

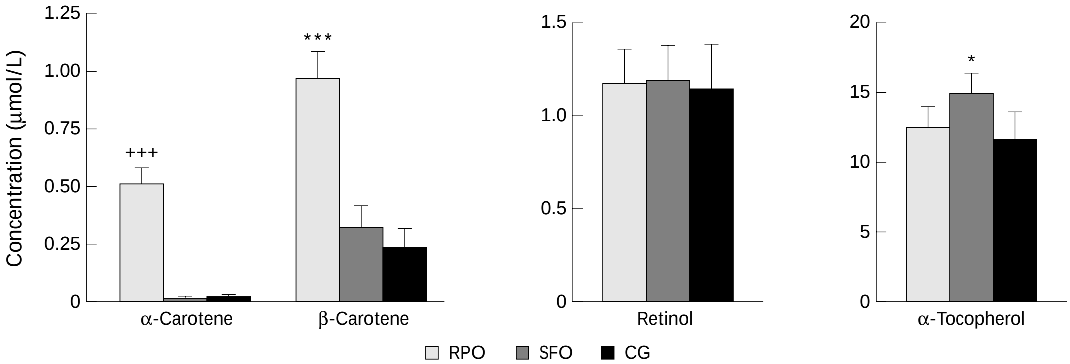

FIG. 1. Geometric mean and 95% confidence intervals of plasma α-carotene, β-carotene, retinol, and α-tocopherol at three months postpartum among women given red palm oil (RPO) or sunflower oil (SFO) and among control women (CG). Significantly different from controls: $^{+++}p < .01$, Kruskal-Wallis test; $^{*}p < .05$, $^{***}p < .001$, analysis of variance

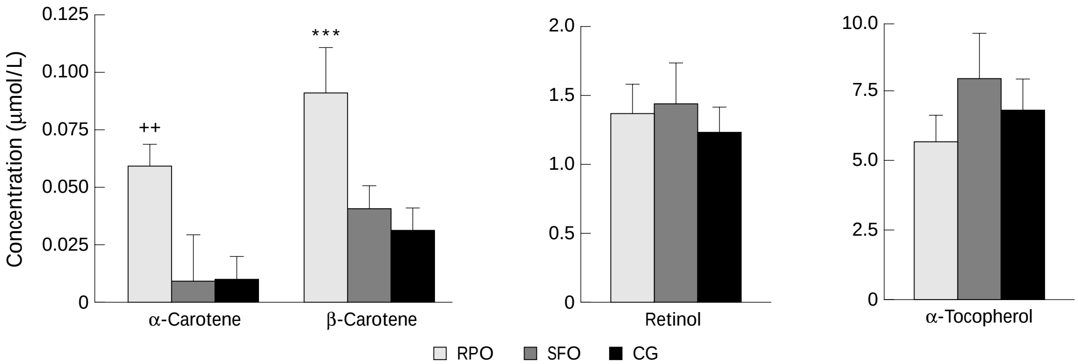

FIG. 2. Geometric mean and 95% confidence intervals of milk α-carotene, β-carotene, retinol, and α-tocopherol at three months postpartum among women given red palm oil (RPO) or sunflower oil (SFO) and among control women (CG). Significantly different from controls: $^{++}p < .01$, Kruskal-Wallis test; $^{***}p < .001$, analysis of variance

TABLE 1. Milk retinol 1 and 3 months postpartum

Treatment	*n*	Retinol (μmol/L) 1 mo	Retinol (μmol/L) 3 mo	Retinol (μmol/kg fat) 1 mo	Retinol (μmol/kg fat) 3 mo
Red palm oil	24–28				
Geometric mean		1.47	1.36	44.50	44.64
95% CI		1.31–1.65	1.17–1.58	38.87–50.94	37.82–52.68
Sunflower oil	25–29				
Geometric mean		1.65	1.43	48.52	46.09
95% CI		1.42–1.93	1.18–1.74	40.98–57.44	39.00–54.47
Control group	25–27				
Geometric mean		1.50	1.22[a]	48.52	38.45[a]
95% CI		1.29–1.74	1.06–1.41	41.34–56.95	33.65–43.93

a. Significantly different from 1 month postpartum ($p < .001$, paired *t* test).

Additionally, the high amounts of α- and β-carotene in both plasma and breastmilk may have other health benefits, since it has been shown that β-carotene capsules markedly decrease pregnancy-related mortality and the incidence of night-blindness during pregnancy and lactation [7]. Furthermore, it was recently shown that elevated β-carotene levels in milk have a beneficial effect on the child's retinol status [13].

The women given sunflower oil (which contains no carotenoids but has large amounts of α-tocopherol) showed enhanced levels of α-tocopherol in their plasma and breastmilk compared with the control group (figs. 1 and 2). Moreover, α-tocopherol was significantly positively correlated with retinol in both plasma ($r = 0.636$, $p < .001$, $n = 79$) and breastmilk ($r = 0.594$, $p < .001$, $n = 80$) at three months postpartum. α-Tocopherol was shown to enhance the lymphatic transport of β-carotene and to increase the conversion of β-carotene into retinol in the intestine of ferrets in a dose-dependent manner [14]. Additionally, vitamin E has been shown to increase the immune response [15] and to slow down the progression of inflammation-induced diseases and HIV infection [16, 17]. Thus, vitamin E might protect retinol in the case of infectious diseases and increase the conversion of β-carotene into retinol in the intestine.

In light of these findings, the role of α- and β-carotene as well as α-tocopherol in dietary oils for maternal health needs to be studied further. Since the provitamin A concentration of breastmilk increased in the group receiving red palm oil, further research needs to be undertaken to examine the effect of these antioxidants on the immune response as well as their impact on infants' vitamin A status.

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References

1. Takahashi YI, Smith ES, Winick M, Goodman DS. Vitamin A deficiency and fetal growth and development in the rat. J Nutr 1975;105:1299–310.
2. Antipatis C, Ashworth CJ, Grant G. Effects of maternal vitamin A status on prenatal development in rats. J Reprod Fertil Abstr Ser 1996;18:82.
3. Underwood BA. Maternal vitamin A status and its importance in infancy and early childhood. Am J Clin Nutr 1994;59(Suppl):517S–24S.
4. Newman V. Vitamin A and breast-feeding: a comparison of data from developed and developing countries. Food Nutr Bull 1994;15:161–76.
5. West KP, Chirambo M, Katz J, Sommer A. The Malawi Survey Group. Breast feeding, weaning patterns, and the risk of xerophthalmia in southern Malawi. Am J Clin Nutr 1986;44:690–7.
6. Mahalanabis D. Breast feeding and vitamin A deficiency among children attending a diarrhoea treatment centre in Bangladesh: a case-control study. BMJ 1991;303:493–6.
7. West KP, Katz J, Khatry SK, LeClerq SC, Pradhan EK, Shrestha SR, Conner PB, Dali SR, Christian P, Pokhrel RP, Sommer A. Double blind, cluster randomised trial of low dose supplementation with vitamin A or beta carotene on mortality related to pregnancy in Nepal. BMJ 1999;318:570–5.
8. Stoltzfus RJ, Hakimi M, Miller KW, Rasmussen KM, Dawiesah S, Habicht JP, Dibley MJ. High-dose vitamin-A supplementation of breast-feeding Indonesian mothers. Effects on the vitamin-A status of mother and infant. J Nutr 1993;123:666–75.
9. Canfield LM, Giuliano AR, Neilson EM, Yap HH, Graver EJ, Cui HA, Blashill BM. Beta-carotene in breast milk and serum is increased after a single beta-carotene dose. Am J Clin Nutr 1997;66:52–61.
10. de Pee S, West CE, Muhilal, Karyadi D, Hautvast J. Lack of improvement in vitamin-A status with increased consumption of dark-green leafy vegetables. Lancet 1995;346:75–81.
11. Rice AL, Stoltzfus RJ, deFrancisco A, Chakraborty J, Kjolhede CL, Wahed MA. Maternal vitamin A or β-carotene supplementation in lactating Bangladeshi women benefits mothers and infants but does not prevent subclinical deficiency. J Nutr 1999;29:356–65.
12. Newman V. Vitamin A and breastfeeding. San Diego, Calif, USA: Wellstart International, 1993.
13. Canfield LM, Kaminsky RG, Liu Y. Red palm oil in the maternal diet improves the vitamin A status of mothers and their nursing infants. 12th International Carotenoid Symposium, Cairns, Australia, 18–23 July 1999. Cairns: International Carotenoid Society, 1999:1A-4 (Abstract).
14. Wang XD, Marini RP, Hebuterne X, Fox JG, Krinsky NI, Russell RM. Vitamin-E enhances the lymphatic transport of beta-carotene and its conversion to vitamin-A in the ferret. Gastroenterology 1995;108:719–26.
15. Meydani SN, Wu DY, Santos MS, Hayek MG. Antioxidants and immune-response in aged persons. Overview of present evidence. Am J Clin Nutr 1995;62:S1462–76.
16. Semba RD, Neville MC. Breast-feeding, mastitis, and HIV transmission: nutritional implications. Nutr Rev 1999; 57:146–53.
17. Filteau SM, Lietz G, Mulokozi G, Bilotta S, Henry CJK, Tomkins A. Milk cytokines and subclinical breast inflammation in Tanzanian women: effects of dietary red palm oil or sunflower oil supplementation. Immunology 1999;97:595–600.

Dietary strategies to combat deficiencies of iron, zinc, and vitamin A in developing countries: Development, implementation, monitoring, and evaluation

R. S. Gibson, C. Hotz, L. Temple, F. Yeudall, B. Mtitimuni, and E. Ferguson

Abstract

In many developing countries, staple diets are plant-based and consumption of animal products is low. As a result, the intake and bioavailability of iron, zinc, and vitamin A are often poor. Deficiencies of these micronutrients can be prevented by using dietary diversification and modification, a strategy involving changes in food production practices, food selection patterns, and traditional household methods for preparing and processing indigenous foods. Strategies at the food production level include the use of fertilizers, plant breeding, and genetic engineering to enhance the content and bioavailability of micronutrients in plant-based staples and increase the yield of indigenous edible wild plants. Household strategies involve small-livestock production, aquaculture, gardening projects, and changes in certain food preparation and processing practices designed to alter the content of absorption modifiers in the diet, such as soaking, germination, fermentation, and enrichment. This review also describes how these household strategies can best be incorporated into existing food consumption patterns, and how their impact on the nutrient adequacy of the diets can be assessed. The steps necessary to test the acceptability of the modified recipes, to identify potential barriers to their adoption, and to implement them in the community are discussed, using an example from rural Malawi. Finally, methods of monitoring the progress and evaluating the impact of the dietary strategies in short- and long-term studies are included.

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Introduction

Deficiencies of iron, vitamin A, and zinc have far-reaching consequences on growth, development, and health, contributing to impairments in immune competence and cognitive function, blindness, anaemia, growth failure, and increased morbidity and mortality. Such deficiencies are widespread in many developing countries and arise from inadequate intakes, impaired absorption or utilization, excessive losses, or a combination of these factors.

In most developing countries, the intake of flesh foods, which are rich sources of readily available iron, zinc, and preformed vitamin A, is small because of socioeconomic, cultural, or religious constraints. Instead, staple diets are predominantly plant-based and therefore contain high levels of polyphenols, dietary fibre, and phytate, components known to inhibit the absorption of non-haem iron and zinc. The bioavailability of β-carotene in dark-green leafy vegetables, a major source of provitamin A in many plant-based diets, is also poor. As a result, the content and bioavailability of iron, zinc, and vitamin A in rural diets in developing countries is often low. In addition, the fat content of the diet is often low, further compromising the absorption and transport of provitamin A carotenoids. Interactions among these co-existing micronutrients (e.g., vitamin A and zinc, vitamin A and iron) may also exacerbate these deficiency states.

Clearly, an intervention strategy that is sustainable without external support and has an ability to combat multiple micronutrient deficiencies simultaneously is urgently required. Dietary diversification and modification is a strategy that meets these needs. The approach involves changes in food production practices, food selection patterns, and traditional household methods of preparing and processing indigenous foods. The overall goal is to enhance the availability, access, and utilization of foods with a high content and bioavailability of micronutrients throughout the year.

Food production strategies to improve the content and bioavailability of iron, zinc, and vitamin A in plant-based staple foods

The nutritional adequacy of iron, zinc, and vitamin A depends on their amount and bioavailability in the diet. Bioavailability can be defined as the proportion of the total micronutrient in a food or diet that is absorbed and utilized for normal physiological functions. There are several strategies that can be used at the food production level to enhance the content or bioavailability of these micronutrients in plant-based staples consumed in developing countries. These are summarized below.

Agricultural and horticultural strategies

Agricultural and horticultural strategies can have a major impact on the iron, zinc, and vitamin A intakes of population groups consuming diets in which at least 40% of their dietary energy is derived from a single staple, such as rice, maize, cassava, or sweet potatoes. The strategies include applying fertilizers to soils or foliage to enhance the zinc and iron content, respectively, of cereal grains, as carried out in certain regions of Turkey where the soil content of zinc is very low. As a result, the zinc concentrations in wheat grains (7–12 mg/kg) are well below the accepted critical levels of zinc for adequate plant nutrition [1].

Plant breeding can also be used to produce cereal varieties with increased grain micronutrient content. In some cases this is achieved by using unavailable iron and zinc in soils or by increasing phloem translocation efficiency, a process whereby certain trace minerals (e.g., iron and zinc) are remobilized from the vegetative parts to the grain [2]. Plant breeding can also be used to increase the β-carotene content of staples such as cassava roots [3] and orange-fleshed sweet potatoes [4], as shown in table 1. More recently, genetic engineering has been used to produce rice grains containing a significant amount of β-carotene in the endosperm as well as an increased content of iron, by using a ferritin transgene from *Phaseolus vulgare* [Potrykus I, Lucca P, Ye X, Al-Babili S, Hurrel R, Beyer P, personal communication, 1999].

Certain indigenous edible wild plants, such as wild fruits, nuts, seeds, and leaves, which are easily cultivated and accepted by local rural communities, can also serve as rich sources of iron, zinc, and provitamin A carotenoids [5]. These may be especially important in the rainy season in some regions. Agronomic and genetic improvements have led to the development of higher-yielding genotypes of some of these wild plants, as well as varieties that are resistant to drought or heat stress and are tolerant of poor soils. In some areas (e.g., Vietnam, the Sahel in Western Africa, Korea, Zambia, and southern Mali), an inventory of certain edible species has been compiled and some analyses of certain minerals and vitamins, including carotenoids, have been undertaken [6–10]. Data on the antinutrient content of these edible wild plants, however, are generally very limited or nonexistent.

TABLE 1. Average carotene concentration in several varieties of cassava roots and sweet potatoes

Plant and variety	Carotene (mg/100 g)
Cassava	
White	0.13
Cream	0.39
Yellow	0.58
Deep-yellow	0.85
Orange	1.26
Sweet potatoes	
Local	0.1
Simama	0.9
Kakamega 4	3.1
Japanese	6.7

Modified from refs. 3 and 4.

Agricultural strategies to alter the content of absorption modifiers in plant-based staple foods

Strategies to alter absorption modifiers of iron and zinc in staple foods may involve increasing the content of absorption enhancers, decreasing the content of absorption inhibitors, or both. For some cereals (e.g., maize) the genetic potential exists for increasing the level of methionine in the mature kernel by plant breeding. This is important because methionine is a promoter of the absorption of zinc and non-haem iron [11]. Genetic engineering has also been used for rice to increase the resorption-enhancing effect of iron from the small intestine by using a transgenic sulphur-rich metallothionein-like protein from *Oryza sativa* [Potrykus I, Lucca P, Ye X, Al-Babili S, Hurrel R, Beyer P, personal communication, 1999].

Plant breeding can also be used to reduce the content of absorption inhibitors by breeding mutants of corn, barley, and rice with more than 50% reduction in levels of phytic acid phosphorus in the kernels [12]. Absorption of iron from tortillas was 49% greater from low-phytic acid "flint" maize (8.2% of iron intake) than from tortillas prepared from its parent wild-type strain (5.5% of iron intake) [13].

Genetic engineering has also been used to introduce a transgene for a heat-stable phytase from *Aspergillus fumigatus* into rice. After only one hour of cooking, the phytic acid content in rice can be reduced almost completely [Potrykus I, Lucca P, Ye X, Al-Babili S, Hurrel R, Beyer P, personal communication, 1999]. Phytase-transgenic seeds in which phytase from *Aspergillus niger* has been packaged into the seeds have also been developed [14]. This microbial phytase enzyme has two pH optima: pH 2.0 and 5.5, and hence can hydrolyse phytic acid in the gastrointestinal tract into inorganic phosphate and myoinositol.

Household strategies to increase the content of iron, zinc, and vitamin A in plant-based diets

To increase the iron, zinc, and vitamin A (as retinol) content of household diets, small-livestock production (e.g., rabbits, cavies, guinea pigs, poultry, geese, and ducks, as well as ruminants) and aquaculture can be promoted, and the consumption of meat, poultry, fish, animal and fish livers, eggs, milk, and milk products encouraged to ensure they are not sold for cash, but targeted to those household members at high risk for these micronutrient inadequacies. In some countries these foods are not consumed because of economic, religious, or cultural beliefs.

Incorporating chicken or fish livers or small dried fish (as powder or whole) into plant-based diets can result in marked increases in their content and density of haem iron, zinc, and vitamin A (as retinol or retinyl esters). Dried fish has the added advantages that it does not require refrigeration and can often be consumed in countries where religious or cultural factors prevent the consumption of meat and poultry. When prepared as a fish flour, it can be used to enrich cereal-based porridges for infant and child feeding. In rural Malawian diets, for example, consumption of a fish-based relish with the afternoon and evening meal can result in increased intake and enhanced absorption of iron, zinc, vitamin A, and fat.

In Thailand beef or chicken livers are used to enrich fish chips, a popular, locally produced snack food that is prepared from a 2:1 mixture of sago flour and tapioca flour and processed by steaming to enhance vitamin A retention. One bag of fish liver chips provides 20% to 30% of the recommended daily allowance of vitamin A for pre-school children, while simultaneously providing a rich source of readily available haem iron and zinc [Tontisirin K, Winichagoon P, personal communication, 1999].

Community and home gardening projects have been promoted extensively to improve micronutrient nutriture, notably of provitamin A carotenoids, by supplying the micronutrients directly,or by increasing household income through the sale of the produce, particularly fruit [15]. In many developing countries, dark-green leafy vegetables, red or yellow fruits (mango, papaya, jackfruit, prickly pear, and cape gooseberry), fruit vegetables (tomato, pumpkin, squash, gourds, and eggplant), and some root vegetables (carrots and yellow-fleshed potato) are the major sources of provitamin A, depending on the season. In countries where production of the oil palm (*Elaeis guineensis*) is widespread (e.g., western Africa coastal countries), the oil is a major source of readily available provitamin A as well as fat, and village-based methods are being developed to improve extraction yields for the provitamin A by 50%. Although red palm oil has been considered the richest known source of provitamin A carotenoids, recent studies suggest that the concentration of vitamin A activity in the buriti palm tree (*Mauritia vinifera* Mart) is tenfold greater than that of red palm oil [16].

In many of these projects, the horticultural crops are carefully selected so that they can be cultivated throughout the year to provide a constant supply of provitamin A carotenoids. Other strategies that are used to ensure a year-round supply of carotenoids are staggering planting dates and selecting a mixture of early-, average-, and late-maturing varieties of produce, for example, mangoes. Nevertheless, there is considerable heterogeneity in the levels of provitamin A carotenoids present in such horticultural crops, which can be attributed to factors such as soil pH, amount of rainfall, seasonality, genetic diversity, stage of maturation, handling conditions, and food preparation and processing methods [17]. To be successful, recipients of these horticultural projects must receive training in production techniques. A training manual in organic agriculture for community extension workers is available [18].

In many countries, solar drying has been advocated as a means of increasing the year-round availability of provitamin A carotenoids. Retention of carotene after solar drying ranges from 40% to 80%, depending on the product, but is higher than that with traditional drying methods. For example, the retinol equivalent (RE) for fresh cow pea leaves is 2,435 RE/100 g, compared with 2,071 RE/100 g for solar-dried leaves and 847 RE/100 g when traditional drying practices are used [19]. Traditional open-air sun-drying has additional disadvantages, such as infestation by insects, contamination from dirt, rodents, and birds, and spoilage from occasional rains. Shade-drying is recommended for certain produce (e.g., baobab leaves in Mali) because of the smaller losses of provitamin A carotenoids compared with the solar drying process.

Several community-based programmes have observed a positive association between home gardening programmes in conjunction with nutrition education and an increased intake of provitamin A carotenoids. Some [15, 20, 21] but not all [22] have also shown a clear impact on biochemical or functional indices of vitamin A status such as night-blindness; possible reasons for these discrepancies are summarized by de Pee and West [23].

In some countries, integration of horticultural and livestock interventions with health and nutrition strategies has led to marked increases in vitamin A intake and reductions in the risk of vitamin A deficiency. For example, in Ethiopia a women-focused dairy goat–farming project was integrated with the production of vitamin A–rich foods (e.g., sweet potatoes, pumpkin, peppers, goat milk, and egg yolks) and combined with health and nutrition education lessons to improve food preparation and feeding practices [15].

Integrated projects have the potential to enhance iron, zinc, and vitamin A nutriture simultaneously, but to date most have focused exclusively on vitamin A. An exception is a recent study in Thailand [24] that aimed to increase knowledge, change attitudes, and improve practices associated with the production and consumption of foods rich in vitamin A, iron, vitamin C, and fat, such as leafy green vegetables, ivy gourd, animal liver, eggs, poultry, and rabbits; zinc intake would also be concomitantly enhanced by these practices. Projects that address such micronutrient inadequacies simultaneously are especially noteworthy in view of the known interactions between vitamin A and zinc, and between vitamin A and iron.

Household strategies to alter the content of absorption modifiers in plant-based diets

At the household level, certain food preparation and processing methods can be promoted to reduce the level of absorption inhibitors or increase the content of absorption enhancers and thus improve the bioavailability of iron, zinc, and provitamin A carotenoids in rural diets. The methods for zinc and non-haem iron have been reviewed in detail [25, 26]. Strategies to reduce the content of inhibitors of absorption of zinc and non-haem iron are based mainly on the diffusion of water-soluble phytate and polyphenols and the enzymatic hydrolysis of phytic acid. Mild heat treatment can be used to increase the bioavailability of carotenoids in green leafy vegetables by releasing bound carotenoids from the food matrix and binding proteins. It can also be used to induce partial degradation of phytic acid and thus enhance the absorption of non-haem iron and zinc in tubers, but probably not in cereals and legumes [27].

Soaking can be used to reduce the phytate content of certain cereals (e.g., maize) and legumes because their phytic acid is stored in a relatively water-soluble form, such as sodium and potassium phytate [28]. For example, 65% to 90% of hexa- and pentainositol phosphate can be removed by soaking maize flour, depending on the method used. Levels of water-soluble phytate range from 10% in defatted sesame meal to 70% to 97% in California small white beans, red kidney beans, corn germ, and soya flakes. Soaking may also remove other antinutrients, such as saponins and polyphenols [29], which are potent inhibitors of non-haem iron absorption [30].

Enzymatic hydrolysis of phytic acid is induced by phytase enzymes, the activities of which are enhanced by soaking, germination, and fermentation. Phytase enzymes hydrolyse penta- and hexaphosphate (IP5 and IP6) to lower inositol phosphates (IP1–IP4) that do not form insoluble complexes with zinc [31, 32].

Germination increases phytase activity as a result of *de novo* synthesis or activation of endogenous phytase and can result in a 50% reduction in the phytic acid content of certain germinated cereals [26, 33]. During germination other antinutrients, including polyphenols and tannins, which are potent inhibitors of the absorption of non-haem iron but not of zinc, are also reduced [34]. Polyphenols are also present in beverages such as tea, coffee, and red wine [30]. Replacing tea and coffee consumed at meals with fruit juices rich in ascorbic acid can prevent the 35% to 64% reduction in non-haem iron absorption noted when these beverages are served with meals [35], while at the same time partially counteracting the inhibitory effect of other phenolic compounds (e.g., flavonoids and chlorogenic acid) and phytic acid. Germination has also been shown to enhance the carotene content of legumes, such as chickpeas, and cereals, such as rice, wheat, and corn [36].

Fermentation can achieve even greater reductions in phytic acid than germination, because microbial phytases can act over a much broader pH range (2.5–5.5) than cereal phytases (4.5–5.0) [37]. Microbial phytases occur naturally on the surface of cereals and legumes or can be introduced by inoculation with a starter culture. Fermentation also has several other advantages. It can reduce the polyphenol content of certain legumes (e.g., African yam beans) to undetectable levels [38]; it reduces the energy required for cooking and improves the safety of the final food product, because the reduced pH inhibits growth of diarrhoeal pathogens; and antimicrobial substances may also be produced. Alternatively, commercial phytase enzymes prepared from *Aspergillus oryzae* or *A. niger* may be used. These phytases facilitate phytate hydrolysis over an even longer fermentation period because they are stable over a broader range of pH (3.5–7.8) and temperature and at the physiological pH conditions of the stomach.

To date, *in vivo* comparisons in humans of the bioavailability of trace elements in fermented versus unfermented staple plant-based foods are limited. Increased *in vitro* measurements of soluble iron have been reported after fermenting porridges prepared from white sorghum and maize with a starter culture, with and without the addition of commercially prepared wheat phytase enzyme [39] (fig. 1). Sandberg et al. [40] recently reported that iron absorption was higher in subjects fed single meals containing white wheat rolls supplemented with phytase-deactivated wheat bran and with added microbial phytase from *A. niger* than in subjects given the same meal with no added microbial phytase (26.1% vs. 14.3%).

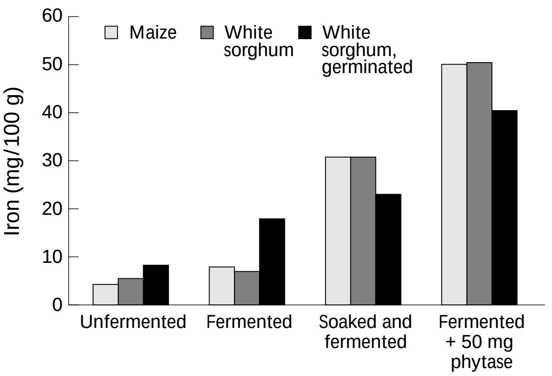

FIG 1. Influence of processing on soluble iron content of sorghum porridges. Modified from ref. 39

Combinations of soaking and thermal processing, or soaking and fermentation as practiced in Malawi in the preparation of refined maize flour (white *ufa* flour), can result in further reductions in the phytic acid content and the phytate:zinc molar ratios.

For cereals in which phytic acid is localized in the outer aleurone layer (rice, sorghum, and wheat) or in the germ (maize), milling can be used to reduce their phytic acid content [41]. Removal of the testes in legumes does not remove their phytic acid content, because it is distributed within the cotyledons [26]. Some home-based milling procedures used in Latin America apparently increase the iron and zinc content of cereals while simultaneously reducing the phytic acid content [42].

The bioavailability of non-haem iron and zinc in household diets can also be improved by the incorporation of certain absorption enhancers, such as animal muscle proteins (meat, poultry, and fish) [43] and organic acids such as citric, malic, lactic, and tartaric acid [44]. Their enhancing effects have been attributed in part to the formation of soluble iron and zinc complexes. The relative enhancing effect of animal muscle proteins on non-haem iron absorption varies. Beef apparently has the highest effect (220%); lamb, pork, liver, and chicken have effects of about 140%; and fish has an effect of about 75% [45, 46]. No comparable data exist for zinc. Inclusion of even a small amount of flesh foods in a meal is likely to increase its fat content and hence facilitate absorption of provitamin A carotenoids and vitamin A by stimulating bile secretion, mixed-micelle formation, and chylomicron formation. Without sufficient fat, the absorption of carotenoids and vitamin A is limited [47].

Ascorbic acid is the most effective enhancer of non-haem iron absorption, provided it is consumed at the same meal as non-haem iron. It can counteract the negative effect of polyphenols or phytic acid on non-haem iron absorption, but it has no effect on zinc absorption. Ascorbic acid promotes non-haem iron absorption by reducing ferric iron to the ferrous state, which is more soluble at the pH present in the duodenum and small intestine (> 3) [48, 49]. Rich sources of ascorbic acid are citrus fruits, guava, carambola, capsicum, white potatoes, and strawberries.

Applying dietary strategies to improve iron, zinc, and vitamin A nutriture in developing countries

Dietary modification and diversification represents a sustainable, economically feasible, equitable, and culturally acceptable strategy that can be used to alleviate several micronutrient deficiencies simultaneously without risk of antagonistic interactions. The strategies are community based and can be used to enhance awareness of micronutrient malnutrition in the community and help to empower people to be more self-reliant.

To implement these dietary strategies effectively, knowledge of local dietary patterns, the availability and cost of foods, and food beliefs, preferences, and taboos is required, as well as the ability to change attitudes and practices. To be effective, the dietary strategies must be practical, culturally acceptable, economically feasible, and sustainable to the target group. They must not increase the cost or the preparation and cooking time, and hence the workload, of the caregivers, or include substantial changes in the types and quantities of food items commonly consumed. Instead, they should be based on existing food consumption patterns, and be adapted from local food processing procedures and recipes.

Assessing food intakes and indigenous methods of preparing and processing foods

The first step in the implementation process involves carrying out a cross-sectional dietary survey to obtain quantitative data on intakes of foods, nutrients, and antinutrients, as well as food processing and preparation methods used in the region, preferably at two seasons of the year to provide information on intake in the food-plenty and food-shortage seasons. To assess intakes of iron and zinc, the food intake data can be collected by three-day weighed food records or modified interactive 24-hour recalls [50]. For vitamin A intake, culture-specific food-frequency questionnaires can be used [51, 52], sometimes with seasonal calendars of food items derived from market and garden surveys.

To gain an understanding of the attitudes and practices about local food habits at this stage, focus groups, in-depth interviews in the household, and observations through participation and systematic observation of food preparation and processing practices should be used. Information on knowledge, attitudes, and self-reported practices (KAP) and behaviours can also be collected by pre-tested questionnaires covering factors that may influence the consumption of foods rich in iron, zinc, and vitamin A, and indigenous methods of food preparation and processing that may have the potential to improve the bioavailability of these micronutrients.

Calculating nutrient and antinutrient intakes from food intake data

The next step is to convert the quantitative food intake data to nutrients and antinutrients, to determine whether the risk of micronutrient inadequacies arises from low intakes, poor bioavailability, or both in local diets, and to identify other limiting nutrients in the diet. In industrialized countries nutrient and antinutrient intakes are usually calculated from food-composition tables or nutrient databases. Unfortunately, in developing countries the nutrient and antinutrient content of local staple foods are often not available. Hence, it is preferable to collect samples of local staple food items within the country, prepare them as eaten, and analyse them for iron, zinc, and vitamin A and for the promoters and antagonists of micronutrient absorption. The analysed values can then be used to compile a local food-composition database. A standardized sampling protocol must be used to collect the food samples for analysis; details are given elsewhere [50].

Atomic absorption spectrophotometry (AAS) is the most widely used method for trace mineral analysis in food samples. For carotenoids and retinol, reverse-phase high-performance liquid chromatography (HPLC) is the recommended method, especially for those food items with mixed carotenoid activity [17]. HPLC is also used for the analysis of the higher- and lower-inositol phosphates [53].

In countries where food analysis is not possible, researchers may wish to purchase a food-composition database together with a software package for calculating intakes of nutrients and antinutrients. The WorldFood Dietary Assessment System [54] contains a comprehensive list of food-composition values for 53 nutrients and associated dietary components (including phytic acid and dietary fibre) for 1,800 foods consumed in Egypt, Kenya, Mexico, Senegal, India, and Indonesia, as well as a computer programme for calculating energy and nutrient intakes (including total and available iron and zinc) and risk of nutrient inadequacy. When food-composition values for provitamin A carotenoids are required, the tables compiled by West and Poortvliet [55] should be used.

Selecting strategies to improve the content and bioavailability of iron, zinc, and vitamin A in household diets

In countries such as Malawi, where unrefined, high-phytate cereals such as maize are used to prepare the main unfermented cereal staple, the first step is to select a method to reduce the hexa- and pentainositol phosphate content of the cereal-based staple. The method selected should be based on local food preparation and processing methods, should not increase the cost, preparation, or cooking time, and should be culturally acceptable to the community. In rural Malawi we selected soaking as the most suitable strategy for maize flour and carried out several trials in our laboratory to establish the extent to which the hexa- and pentainositol phosphate content of the maize-based Malawian staples (*nsima* and porridge) could be reduced by soaking. The results are summarized in table 2. Hexa- and pentainositol phosphate analysis was carried out by HPLC using a modified method of Lehrfeld [53].

Next, the food intake data collected, as described earlier, are used to develop menus for the target group. In these menus the content and bioavailability of iron, zinc, and vitamin A are enhanced, but they do not have substantial changes in the types and quantities of food items commonly consumed. Hence, the modified menus should be based on the energy content of the meals calculated from the food intake data of the target group, together with combinations of local foods optimized to enhance the content and bioavailability of iron, zinc, and vitamin A. The portion sizes should be within the first and third quartiles of those actually consumed, as described in Ferguson et al. [56].

TABLE 2. Effect of processing methods on the mean (± SD) pentainositol phosphate (IP5) and hexainositol phosphate (IP6) content of maize-based porridges

Processing method	*n*	IP6 + IP5 (mg/g dry wt)	Range	% of control
Unprocessed maize flour (control)	8	8.29 ± 1.05	—	—
Soaking maize flour				
Decanting	2	2.31 ± 1.00	1.60–3.01	28
Centrifuging	4	0.95 ± 0.16	0.80–1.12	11
Soaking pounded maize	3	3.00 ± 0.20	2.84–3.23	36

TABLE 3. Menus for four- to six-year-old Malawian children with modified combinations of local foods to enhance micronutrient content and bioavailability

Meal	Food-plenty season	Portion size (g)	Food-shortage season	Portion size (g)
Morning	Boiled groundnuts	123	Sweet potatoes	100
	Bananas	50	Kalongonda	150
Afternoon	Nsima	280	Nsima	250
	Small fish relish	70	Small fish relish	70
	Pumpkin	151	Corn	70
	Boiled groundnuts	79	Mango	90
Evening	Nsima	296	Nsima	250
	Small fish relish	35	Small fish relish	70
	Pumpkin leaf relish with groundnut flour and fresh tomatoes	80		

An example of a modified menu devised for children in rural southern Malawi is shown in table 3. It incorporates the following strategies: changes in the portion sizes and the types of relishes (e.g., small fish, okra, legumes, and small fish plus pumpkin leaves); consumption of boiled groundnuts for snacks to enhance non-haem iron, zinc, and fat content; use of nsima and porridge prepared from soaked, pounded, unrefined maize flour with a reduced phytate content; addition of fresh chopped tomatoes to relish to improve non-haem iron absorption; addition of groundnut flour to pumpkin leaf relish to increase the fat content and thus the absorption of carotenoids; use of pumpkin and pumpkin leaf relish in food-plenty seasons to enhance the content of provitamin A carotenoids and the zinc content of the menu; and inclusion of mango in the food-shortage season to enhance the content of provitamin A carotenoids.

Table 4 compares the nutrient and antinutrient content of these modified menus, calculated from our Malawian food-composition database, with the corresponding actual intakes for children in rural southern Malawi. The WorldFood Dietary Assessment [54] could also be used to perform these calculations.

The results shown in table 4 confirm that our dietary modifications and diversifications proposed in the modified menus markedly reduced the phytate:zinc molar ratios of the Malawian diets while simultaneously increasing their content of other limiting nutrients, such as protein, calcium, and riboflavin.

TABLE 4. Comparison of recommended and actual median energy and nutrient intakes, and the phytate:zinc molar ratio with amounts provided by modified menus according to season

		Food-plenty season		Food-shortage season	
Energy or nutrient	Recommended[a]	Actual	Menu	Actual	Menu
Energy (kcal)	1,480	1,297	1,296	1,045	1,050
Protein (g)	17.2	32.4	60.0	24.8	47.0
Zinc (mg)	9.2[b] or 12.9[c]	6.9	7.3	5.5	7.1
Iron (mg)	14[d]	14.2	15.9	11.2	9.3
Calcium (mg)	400–500	308	769	293	829
Vitamin A (RE)[e]	300	NV[f]	494	NV	363
Vitamin C (mg)	20	163	64	139	132
Thiamine (mg)	0.4–0.5	0.95	0.9	0.7	0.7
Riboflavin (mg)	0.6–0.7	0.6	0.7	0.4	0.4
Niacin (mg)	6.9–8.6	11.2	8.9	6.3	6.7
Phytate: zinc	<12	25	10	27	11

Abbreviations: RE, retinol equivalents; NV, no value.
a. Sources: refs. 57-60.
b. Basal value.
c. Normative zinc requirements assuming low zinc bioavailability.
d. Value for low-bioavailability meals.
e. Retinol equivalent.
f. No value.

Testing the feasibility and acceptability of the proposed dietary strategies in the community using a participatory approach

Despite the potential enhancement in the content and bioavailability of iron, zinc, and vitamin A, as well as other limiting nutrients such as calcium and riboflavin, adoption of the menus incorporating these dietary strategies could potentially have some negative consequences in terms of increasing the cost, preparation and cooking times, or risk of contamination by microbial pathogens, or altering the organoleptic qualities of the overall diets. Consequently, the feasibility and acceptability of the proposed dietary strategies must be tested in the communities, in an effort to identify any negative consequences and potential barriers to their adoption by rural families.

A participatory approach should be used to assess the acceptability of the newly developed recipes and menus to the caregivers and to modify them, where necessary, in an effort to enhance their adoption and sustainability, as recommended by Shrimpton [61]. The approach focuses on building relationships with the community and involving them in the design, implementation, and monitoring and evaluation processes. Details on how to train people in participatory methods are described by Pretty et al. [62]. Methods aimed to strengthen the leadership abilities of community women include the Cornell Modified Community-Based Nutrition Monitoring [63] and the Appreciation-Influence-Control Process [64].

In our studies in Malawi, the participatory research process began with the formulation of an organizational structure for community participation and ownership at the national, regional, district, and programme area levels, as described earlier [65]. A series of workshops was held in the communities to mark the beginning of each dietary intervention strategy. District officers and field staff representing the ministries of health, agriculture, and community development, a nongovernmental organization, community leaders, and health club members (both male and female) were invited to attend the workshops, which were planned by a team of specialists in home economics, agriculture, food and nutrition, psychology, rural extension, and community nutrition. For the Malawian interventions on children aged three to seven years and weanlings, the workshops emphasized maize processing to reduce the phytate content of maize flour, use of enriched porridges to enhance micronutrient density, frequency of feeding (for weanlings and young children), and meal planning. For the weanling intervention, a workshop was also organized on the preparation of thick porridges with amylase-rich flours added to enhance their energy and nutrient density by reducing their viscosity to a consistency suitable for infant feeding without the addition of water.

After the workshops, the designated community leaders held demonstrations to teach small groups about the intervention strategies. During each demonstration, the purpose was described, the process was demonstrated, and a meal was prepared. Caregivers were given samples to taste and were interviewed individually on the organoleptic qualities and perceived barriers to acceptance.

Implementing, monitoring, and evaluating the dietary strategies in the community

Once consensus has been reached in the community on the feasibility and acceptability of incorporating the dietary strategies into local recipes and menus, the final steps involve designing nutrition education messages and social marketing strategies for implementing the strategies, as well as selecting appropriate indicators for monitoring their progress and evaluating their impact on micronutrient nutriture. Social marketing has been used extensively for promoting the consumption of vitamin A–rich foods in several developing countries [21, 66, 67], but its use in implementing dietary strategies for enhancing iron and zinc nutriture is more limited.

Implementing the dietary strategies in the community

For studies on weanlings and children in Malawi, the messages were taught to households by the local research team during face-to-face home-counselling visits and later promoted by social marketing techniques such as drama and music through village bands, drama groups, and community events such as festivals and competitions. To implement the strategies in the weanling study, trials of improved practices procedures were used [68]. In other countries, such as Thailand, school-based nutrition education campaigns have been used to promote health and nutrition messages and to enhance the micronutrient content of school lunch programmes [24]. Radio broadcasts have also been extensively used for promotional messages designed to increase community awareness of the prevention of micronutrient malnutrition, its causes, and its consequences [67].

Monitoring the progress and evaluating the impact of the dietary strategies

Throughout the implementation of the intervention, process indicators should be used to assess whether the dietary strategies are actually being delivered as planned (i.e., whether they are reaching the intended target group and in the appropriate amounts), and where adjustments may be needed. Tables 5 and 6 present examples of process indicators that can be used to monitor

TABLE 5. Selected process indicators for monitoring inputs to dietary diversification or modification programmes

Agriculture	Availability of new cultivars, etc.
Horticulture	Distribution of seeds and plants; training for school community and gardens
Food preparation, preservation, and processing	Formation of women's groups on fermentation, soaking, solar drying, etc.
Nutrition communication and social marketing material	Development of multimedia and support Duration and frequency of communication with target groups
Community participation	Formation of village committees Use of local staff; participation in food production activities

TABLE 6. Selected output indicators for monitoring food-based programmes

Agriculture	Numbers of farmers adopting new cultivars Market availability, etc.
Horticulture	Numbers of community, school, and home gardens started Monthly availability of micronutrient-rich foods in market
Food preparation, preservation, and processing	Amount of solar-dried food produced Number of caregivers soaking maize flour Number of solar driers used
Nutrition communication and social marketing	Media coverage; community and school participation Number of radio and television bulletins and recipe booklets produced
Community participation	Number of village committees, groups, and staff
	Linkages to other groups

input activities and outputs in dietary diversification and modification programmes. A detailed review of methods for monitoring and evaluating vitamin A programmes, including those based on dietary strategies, is given elsewhere [69].

The final phase is to evaluate the impact of the programme, using appropriate outcome indicators. It is critical that the outcome indicators selected are realistic in relation to their ability to respond over the range of improvement expected, the time frame of the intervention, and the characteristic of the target group (e.g., severity of micronutrient malnutrition). Selection of the outcome indicators should also take into account the presence of possible confounders, feasibility, the cost of collection, and the interpretation of the data [70].

For short-term dietary diversification and modification programmes, assessment of changes in knowledge and practices, food-related behaviour, food consumption patterns, and intake of micronutrients and antinutrients is more realistic and achievable than measurement of impact based on biological indicators of iron, zinc, and vitamin A status. The surveys on knowledge and practices and food-related behaviour are based on pre-tested questionnaires, which should be conducted at baseline and post-intervention, sometimes on a representative subsample of the target group. They can be used to ascertain why a programme may not have had any impact. To evaluate the impact of the dietary strategies in relation to changes in micronutrient adequacy, micronutrient intakes at baseline and post-intervention should be compared with the estimated physiological requirements set by the Food and Agricultural Organization (FAO) and the World Health Organization (WHO) [59, 60], taking into account the bioavailability of the micronutrients in the local diets. When the WorldFood Dietary Assessment System is used, intakes of available iron and zinc, based on the algorithms developed by Murphy et al. [71], are calculated by the computer programme.

Biological indicators may be a combination of biochemical, functional, and clinical indices of iron, zinc, and vitamin A status; the choice depends on factors such as performance (sensitivity, specificity, and predictive value), cultural acceptability, technical feasibility, and cost. Clinical indicators are most useful during the advanced stages of deficiency, when overt signs and symptoms of micronutrient deficiencies exist. Unfortunately, biological indicators are often affected by biological and technical factors other than depleted stores of the micronutrients, which may confound the interpretation of the results. The effects of these confounding factors can be minimized or eliminated by standardizing the sampling and collection procedures for the biological samples (blood, hair, or urine) by an appropriate evaluation design and, in some cases, by measuring the confounding factors concomitantly (e.g., infection) so that they can be taken into account in the statistical analysis. For all indicators, standardized methodology, calibrated equipment, and trained research assistants must be used.

For community-based studies, examples of biochemical indices for iron include comparison of the haemoglobin distribution curve of the target population with that of a healthy reference population [72] and changes in serum ferritin or zinc protoporphyrin values pre- and post-intervention, in association with haemoglobin values. For vitamin A, changes in serum or breastmilk retinol content (sometimes expressed in relation to breastmilk fat concentrations) are often measured. A new test that measures the endogenous fluorescence of vitamin A in combination with retinol-binding protein (holo-RBP) has recently been developed. For zinc, measurements of plasma or hair zinc concentrations are the most useful indices at the present time [73].

Functional indices of iron status include the assessment of immune competence and possibly work capacity in adults. For zinc, assessment of growth and body composition, possibly the dual sugar permeability test using lactulose and mannitol for measuring intestinal permeability, and illness-related indicators, such as the number and duration of acute or chronic diarrhoeal episodes and upper and lower respiratory infections, have been used. Several functional indices specific for vitamin A have been developed. These include assessment of rapid dark adaptation time, vision restoration time, and conjunctival impression cytology, with and without transfer. A new pupillary dark adaptation test that can be used to screen populations for night-blindness also holds promise [73]. In long-term intervention studies involving large sample sizes, changes in mortality rates among infants and one- to three-year-olds may be used as outcome indicators.

Evaluation of biochemical and functional indices of micronutrient status may involve comparing the prevalence of persons with values below designated cut-off values, pre- and post-intervention, and/or between the intervention and a control group, as well as changes in the distribution of the indices in the target population pre- and post-intervention and/or between the intervention and a control group. For physiological functional indicators that do not have established cut-off points, comparison of changes in the distribution of the indices pre- and post-intervention is often the only method available.

Conclusions

Dietary diversification and modification strategies are available for improving simultaneously the iron, zinc, and vitamin A nutriture of rural populations in developing countries who consume predominantly plant-based diets. The strategies can be adapted to local conditions and readily incorporated into existing local recipes and menus, without increasing the cost of meals, their preparation or cooking time, or the workload of the caregivers. Implementation of the strategies must be undertaken by using a participatory approach to ensure that they are feasible and acceptable to caregivers in the local communities, and thus sustainable. Ongoing nutrition education and social marketing efforts are required to enhance the adoption of the dietary strategies and to empower the community to sustain them. Finally, the progress of the dietary strategies should be monitored and their impact evaluated by both qualitative and quantitative methods. First, changes in knowledge and practices of the caregivers can be evaluated and changes in dietary intakes can be assessed pre- and post-intervention, between the intervention and a control group, or both. For longer-term programmes, their impact can be evaluated by biological indicators that may include biochemical and functional indices of micronutrient status.

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References

1. Cakmuk I, Erdal I. Phytic acid-zinc molar ratios in wheat grains grown in Turkey. Micronutr Agric 1996;2:7–18.
2. Graham RD, Welch RM. Breeding for staple food crops with high micronutrient density. Working Papers on Agricultural Strategies for Micronutrients, No. 3. Washington, DC: International Food Policy Research Institute, 1996.
3. Iglesias C. Genetic potential and stability of β-carotene content in cassava roots. Micronutr Agric 1996;2:2–14.
4. Hagenimana V, Oyunga MA, Low J, Gichuki S, Kabira J. The effects of women farmers' adoption of orange-fleshed sweet potatoes: raising vitamin A intake in Kenya. Washington, DC: International Center for Research on Women, 1999.
5. Shrimpton R. Vitamin A deficiency in Brazil: perspectives for food production orientated interventions. Ecol Food Nutr 1989;23:261–71.
6. Duc BM. Study of the nutritive value and utilization of wild vegetables in Viet Nam. In: Applied nutrition. Proceedings of the International Conference on Applied Human Nutrition. Hanoi, Vietnam: National Institute of Nutrition and UNICEF, 1988:327–33.
7. Becker B. Wild plants for human nutrition in the Sahelian zone. J Arid Environ 1986;11:61–4.
8. Kim SH, Oh S-Y. Cultural and nutritional aspects of traditional Korean diet. World Rev Nutr Dietet 1996; 79:109–32.
9. Malaisse F, Parent G. Edible wild vegetable products in the Zambezian woodland area. A nutritional and ecological approach. Ecol Food Nutr 1985;18:43–82.
10. Noreide MB, Hatloy A, Folling M, Lied E, Oshang A. Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district in Kovtiala, southern Mali. Int J Food Sci Nutr 1996;47:455–68.
11. House WA, Van Campen DR, Welch RM. Supplemental sulfur-containing amino acids enhance the bioavailability to rats of zinc in corn kernels. Nutr Res 1996;16:225–35.
12. Raboy V, Below FE, Dickinson DB. Alterations of maize kernel phytic acid levels by recurrent selection for protein and oil. J Hered 1989;80:311–5.
13. Mendoza C, Viteri FE, Lonnerdal B, Young KA, Raboy V, Brown KH. Effect of genetically modified, low-phytic acid maize on absorption of iron from tortillas. Am J Clin Nutr 1998;68:1123–7.
14. Pen J, Verwoerd TC, van Paridon PA, Beuedker RF, van den Elzen PJM, Geerse K, van der Klis JD, Versteegn HAJ, van Ooyen AJJ, Hoekema A. Phytase-containing transgenic seeds as a novel feed additive for improved phosphorus utilization. Bio Technol 1993;11:811–4.
15. Ayalew W, Gebriel ZW, Kassa H. Reducing vitamin A deficiency in Ethiopia: linkages with a women-focused dairy goat farming project. Washington, DC: International Center for Research on Women, 1999.
16. Rains-Mariath JG, Cavalcanti Lim MC, Pacheco Santos LM. Vitamin A activity of buriti (*Mauritia vinifera* Mart) and its effectiveness in the treatment and prevention of xerophthalmia. Am J Clin Nutr 1989;49:849–53.
17. Booth SL, Johns TA, Kuhnlein HV. The complexities of understanding vitamin A in food and diets: the problems. In: Kuhnlein HV, Pelto GH, eds. Culture, environment and food to prevent vitamin A deficiency. Boston, Mass, USA, and Ottawa, Canada: International Foundation for Developing Countries and International Development Research Centre, 1997:11–29.
18. Burgess A, Maina G, Harris P, Harris S. How to grow a balanced diet: a handbook for community workers. London: VSO Books, 1999.
19. FAO/WHO. The vitamin A programme. Fifth summary progress report 1993–1994. Rome: Food and Agriculture Organization, 1995.
20. Yusuf HKM, Islam MN. Improvement of nightblindness situation in children through simple nutrition education intervention with the parents. Ecol Food Nutr 1994; 31:247–56.
21. de Pee S, Bloem MW, Satoto, Yip R, Sukaton A, Tjiong R, Shrimpton R, Muhilal, Kodyat B. Impact of a social marketing campaign promoting dark-green leafy vegetables and eggs in Central Java, Indonesia. Int J Vitam Nutr Res 1998;68:389–98.
22. Smitasiri S, Attig GA, Valyasevi A, Dhanamitta S, Tontisirin K. Social marketing vitamin A–rich foods in Thailand. A model nutrition communication for behavior change process. Salaya, Thailand: Institute of Nutrition, Mahidol University, 1993.
23. de Pee S, West CE. Dietary carotenoids and their role in combating vitamin A deficiency: a review of the literature. Eur J Clin Nutr 1996;50:S38–53.
24. Smitasiri S, Dhanamitta S. Sustaining behavior change to enhance micronutrient status: community- and women-based interventions in Thailand. Washington, DC: International Center for Research on Women, 1999.
25. Gibson RS, Donovan UM, Heath A-L. Dietary strategies to improve the iron and zinc nutriture of young women following a vegetarian diet. Plant Foods Hum Nutr 1997;51:1–16.
26. Gibson RS, Ferguson EL. Nutrition intervention strategies to combat zinc deficiency in developing countries. Nutr Res Rev 1998;10:1–18.
27. Marfo EK, Simpson BK, Idowu JS, Oke OL. Effect of local food processing on phytate levels in cassava, cocoyam, yam, maize, sorghum, rice, cowpea, and soybean. J Agric Food Chem 1990;38:1580–5.
28. De Boland AR, Garner GB, O'Dell BL. Identification and properties of phytate in cereal grains and oilseed products. J Agric Food Chem 1975;23:1186–9.
29. Kataria A, Chauhan BM, Gandhi S. Effect of domestic processing and cooking on the antinutrients of black gram. Food Chem 1988;30:149–56.
30. Brune M, Rossander L, Hallberg L. Iron absorption and phenolic compounds: importance of different phenolic structures. Eur J Clin Nutr 1989;43:547–58.
31. Lönnerdal B, Sandberg A-S, Sandström B, Kunz C. Inhibitory effects of phytic acid and other inositol phosphates on zinc and calcium absorption in suckling rats. J Nutr 1989;119:211–4.
32. Brune M, Rossander L, Hallberg L, Gleerup A, Sandberg A. Iron absorption from bread in humans: inhibiting effects of cereal fiber, phytate, and inositol phosphates with different numbers of phosphate groups. J Nutr 1992;122:442–9.

33. Lorenz K. Cereal sprouts: composition, nutritive value, food applications. CRC Crit Rev Food Sci Nutr 1980; 3:353–85.
34. Camacho L, Sierra C, Campos R, Guzman E, Marcus D. Nutritional changes caused by germination of legumes commonly eaten in Chile. Arch Latinoam Nutr 1992;42:283–90.
35. Rossander-Hulten L, Hallberg L, Bjorn-Ramussen E. Absorption of iron from breakfast meals. Am J Clin Nutr 1979;32:2484–9.
36. Chattopadhay H, Banerjee S. Effect of germination on the carotene content of pulses and cereals. Science 1951;113:600–1.
37. Sandberg A-S. The effect of food processing on phytate hydrolysis and availability of iron and zinc. In: Friedman M, ed. Nutritional and toxicological consequences of food processing. New York: Plenum Press, 1991:499–508.
38. Ene-Obong HN, Obizoba IC. Effect of domestic processing on the cooking time, nutrients, antinutrients and *in vivo* protein digestibility of the African yambean (*Spenostylis stenocarpa*). Plant Foods Hum Nutr 1996; 49:43–52.
39. Svanberg U, Lorri W, Sandberg A-S. Lactic fermentation of non-tannin and high-tannin cereals: effects on *in vitro* estimation of iron availability and phytate hydrolysis. J Food Sci 1993;58:408–12.
40. Sandberg A-S, Rossander-Hulthen L, Turk M. Dietary *Aspergillus niger* phytase increases iron absorption in humans. J Nutr 1996;126:476–80.
41. O'Dell BL, de Bowland AR, Koirtyohann SR. Distribution of phytate and nutritionally important elements among the morphological components of cereal grains. J Agric Food Chem 1972;20:718–21.
42. Krause VM, Kuhnlein HV, Lopez-Palacios CY, Tucker KL, Ruz M, Solomons, NW. Preparation effects on tortillas mineral content in Guatemala. Arch Latinoam Nutr 1993;43:73–7.
43. Hallberg L, Rossander L. Improvement of iron nutriture in developing countries: comparisons of adding meat, soy protein, ascorbic acid, citric acid, and ferrous sulphate on iron absorption from a simple Latin-American-type of meal. Am J Clin Nutr 1984;39:577–83.
44. Charlton RW. The effects of organic acids, phytates, and polyphenols on the absorption of iron from vegetables. Br J Nutr 1983;49:331–42.
45. Cook JD, Monsen ER. Food iron absorption in human subjects. 3. Comparison of the effect of animal proteins on non-heme iron absorption. Am J Clin Nutr 1976;29:859–67.
46. Lynch SR, Hurrell RF, Dassenko SA, Cook JD. The effect of dietary proteins on iron bioavailability in man. Adv Exp Med Biol 1989;248:117–32.
47. Reddy V, Vijayaraghavan K. Carotene rich foods for combating vitamin A deficiency. Hyderabad, India: National Institute of Nutrition, 1995:39–43.
48. Hallberg L, Brune M, Rossander L. Iron absorption in man: ascorbic acid and dose-dependent inhibition by phytate. Am J Clin Nutr 1989;49:140–4.
49. Bendich A, Cohen M. Ascorbic acid safety: analysis of factors affecting iron absorption. Toxicol Lett 1990; 51:189–201.
50. Gibson RS, Ferguson E. An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. Washington, DC: International Life Sciences Institute Press (in press).
51. International Vitamin A Consultative Group. Guidelines for the development of a simplified dietary assessment to identify groups at risk for inadequate intake of vitamin A. Washington, DC: International Life Sciences Institute, Nutrition Foundation, 1989.
52. Rosen DB, Haslow NJ, Sloan NL. How to use the HK food frequency method to assess community risk of vitamin A deficiency. New York: Helen Keller International Vitamin A Technical Assistance Program, 1994.
53. Lehrfeld J. High-performance liquid chromatography analysis of phytic acid on a pH-stable, macroporous polymer column. Cereal Chem 1989;66:510–5.
54. Bunch S, Murphy SP. User's guide to the operation of the World Food Dietary Assessment Program. Berkeley, Calif, USA: Office of Technology Licensing, University of California, 1994.
55. West CE, Poortvliet EJ. The carotenoid content of foods with special reference to developing countries. Arlington, Va, USA: International Science and Technology Institute, 1993.
56. Ferguson EL, Gibson RS, Opare-Obisaw C, Ounpuu S, Lamba C. Dietary strategies for improving the zinc nutriture of rural southern Malawian and Ghanaian children. Ecol Food Nutr 1995;34:33–47.
57. FAO/WHO. Handbook on human nutritional requirements. World Health Organization Monograph Series No. 61. Rome: Food and Agriculture Organization, 1974.
58. FAO/WHO/UNU. Energy and protein requirements. World Health Organization Technical Report Series 724. Geneva: World Health Organization, 1985.
59. FAO/WHO. Requirements of vitamin A, iron folate and vitamin B-12. Rome: Food and Agriculture Organization, 1988.
60. WHO. Trace elements in human nutrition and health. Geneva: World Health Organization, 1996.
61. Shrimpton R. Community participation in food and nutrition programs: an analysis of recent government experiences. In: Pinstrup-Andersen P, Pelletier D, Alderman H, eds. Child growth and nutrition in developing countries. Ithaca, NY, USA: Cornell University Press, 1995:243–61.
62. Pretty JN, Guijt I, Thompson J, Scoones I. Training in participant methods in the workshop. In: Participatory learning and action: a trainer's guide. London: Sustainable Agriculture Programme, International Institute for Environment and Development, 1995:72–89.
63. Pelletier DL, Kraak V, Ferri-Morris M. The CBNM problem solving model: an approach for improving nutrition research decision-making in the community. A manual prepared for the CBNM strategy workshop. Ithaca, NY, USA: Division of Nutrition Science, Cornell University, 1994.
64. Smith WE, Landais FL. A new approach to organizing and planning. Dev Southern Afr 1991;8:223–38.
65. Gibson RS, Yeudall F, Drost N, Mtitimuni B, Cullinan T. Dietary interventions to prevent zinc deficiency. Am J Clin Nutr 1998;68(Suppl):484S–7S.

66. Smitasiri S, Attig GA, Dhanamitta S. Participatory action for nutrition education: social marketing vitamin A–rich foods in northeast Thailand. Ecol Food Nutr 1992;28:199–210.
67. Graciano F, ed. Localvita Baseline Survey results: South Sulawesi launch of SUVITAL (the social marketing campaign for the promotion of vitamin A–rich foods) in Ujung Pandang. Jakarta, Indonesia: Helen Keller International, 1997.
68. Dicken K, Griffiths M, Piwoz E. Designing by dialogue: a program planners' guide to consultative research for improving young child feeding. Washington, DC: Support for Analysis and Research in Africa, 1997.
69. Cervinskas J, Houston R. Monitoring vitamin A programs. Ottawa, Canada: Micronutrient Initiative, 1998.
70. Sahn DE, Lockwood R, Scrimshaw NS, eds. Methods for the evaluation of the impact of food and nutrition programmes. Food Nutr Bull (Suppl 8). Tokyo: United Nations University Press, 1981.
71. Murphy SP, Beaton GH, Calloway DH. Estimated mineral intakes of toddlers: predicted prevalence of inadequacy in village populations in Egypt, Kenya and Mexico. Am J Clin Nutr 1992;56:565–72.
72. Yip R, Stoltzfus RJ, Simmons WK. Assessment of the prevalence and the nature of iron deficiency for populations: the utility of comparing haemoglobin distributions. In: Hallberg L, Asp N-G, eds. Iron nutrition in health and disease. London: John Libbey, 1996:31–48.
73. Wasantwisut E, Rosado J, Gibson RS. Nutritional assessment: methods for selected micronutrients and calcium. In: Encyclopedia of Life Support Systems. Paris: UNESCO and EOLSS (in press).

Evaluating food-based programmes for their reduction of vitamin A deficiency and its consequences

Saskia de Pee, Martin W. Bloem, and Lynnda Kiess

Abstract

Food-based approaches, using foods naturally rich in micronutrients, are one strategy for combating micronutrient deficiencies. They can have both a direct impact on nutritional status and health by changing the production, preparation, and consumption of foods, and an indirect impact by changing associated aspects such as income, expenditure, and empowerment of women. This combination of a direct and an indirect impact, each of which can also be confounded by other factors, complicates the evaluation of the impact of food-based approaches. In order to develop food-based approaches into a sound and well-recognized strategy for combating micronutrient deficiencies, with appropriate appreciation of their possible impact as well as of their limitations, food-based programmes have to be evaluated for their impact on nutritional status and health. This paper suggests ways to do this by using a conceptual framework for designing the programme and evaluating its impact, studying the relationship between the consumption of particular foods and nutritional status, and assessing the contribution of a food-based programme to reducing the risk of vitamin A deficiency relative to other programmes. One of the main conclusions is that intervention studies can be used to study particular relationships identified by the conceptual framework, such as the relationship between increased consumption of leafy vegetables and vitamin A status, but that specific evaluations are necessary to assess the impact of a particular food-based programme, because of the many confounding factors that are difficult to take into account in a smaller-scale intervention study.

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Introduction

Food-based approaches using foods naturally rich in micronutrients are one of four types of strategies for combating micronutrient deficiencies. The other types are supplementation with high- or low-dose pharmaceutical preparations, food fortification, and public health interventions, such as immunization and improvement of hygienic conditions. Supplementation and food fortification have a direct impact on micronutrient deficiencies, because they increase the intake of one or more particular micronutrients, and public health interventions have an indirect impact. Food-based approaches have both a direct impact, by changing the production, preparation, and consumption of foods, and an indirect impact, by changing associated aspects such as income, expenditure, and empowerment of women. This combination of a direct and an indirect impact, each of which can also be confounded by other factors, complicates the evaluation of the impact of food-based approaches.

In addition, it has recently been recognized that the effectiveness of plant foods, especially of dark-green leafy vegetables, for improving vitamin A status is lower than has long been assumed [1–3]. As a result, the role of food-based programmes, in particular of those that focus on increasing the production and consumption of dark-green leafy vegetables, in improving vitamin A status has been questioned. However, evaluations should take into account effects of gardening programmes on vitamin A status other than those resulting from the production of vitamin A–rich foods.

We would like to contribute to the assessment of the role of food-based approaches in reducing vitamin A deficiency and improving health by discussing a conceptual framework that can be used for assessing in what ways and to what extent food-based programmes can contribute to combating vitamin A deficiency and improving health, and by discussing how different types of studies and evaluations can help to elucidate and quantify the relationships as identified by the framework. It is important to note that we specifically focus on the role of food-based programmes in combating vitamin A deficiency and its consequences, but that in many cases the discussion can be extended to other vitamins and minerals as well as to health.

Conceptual framework

In order to identify ways food-based programmes can improve nutritional status and health, the IUNS Committee II/8 "Food Gardening for Nutrition Improvement" modified UNICEF's conceptual framework for causes of malnutrition [4] to accommodate the effects of food-based programmes. Figure 1 shows the modified framework, with rectangles representing different activities of food-based programmes and where they can interact with the pathways that lead to changes of nutritional status. Examples of food-based programmes are homestead food production* for increasing the availability, and subsequently the consumption, of vitamin A–rich foods; social marketing for increasing the consumption of vitamin A–rich foods; and food processing in order to extend the period during which vitamin A–rich foods are available for consumption or reducing bulk by reducing liquid content, such as by solar drying of fruits or vegetables [7, 8]. Any food-based programme should increase the consumption or utilization of vitamin A–rich foods and subsequently lead to an improvement of vitamin A status and health. As shown in the framework, the pathways for achiev-

* Soleri and Cleveland [6] defined a homestead garden as "a supplementary food production system which is under the management and control of household members. A household garden can be consumption or market oriented, but at least some produce will be consumed by the household."

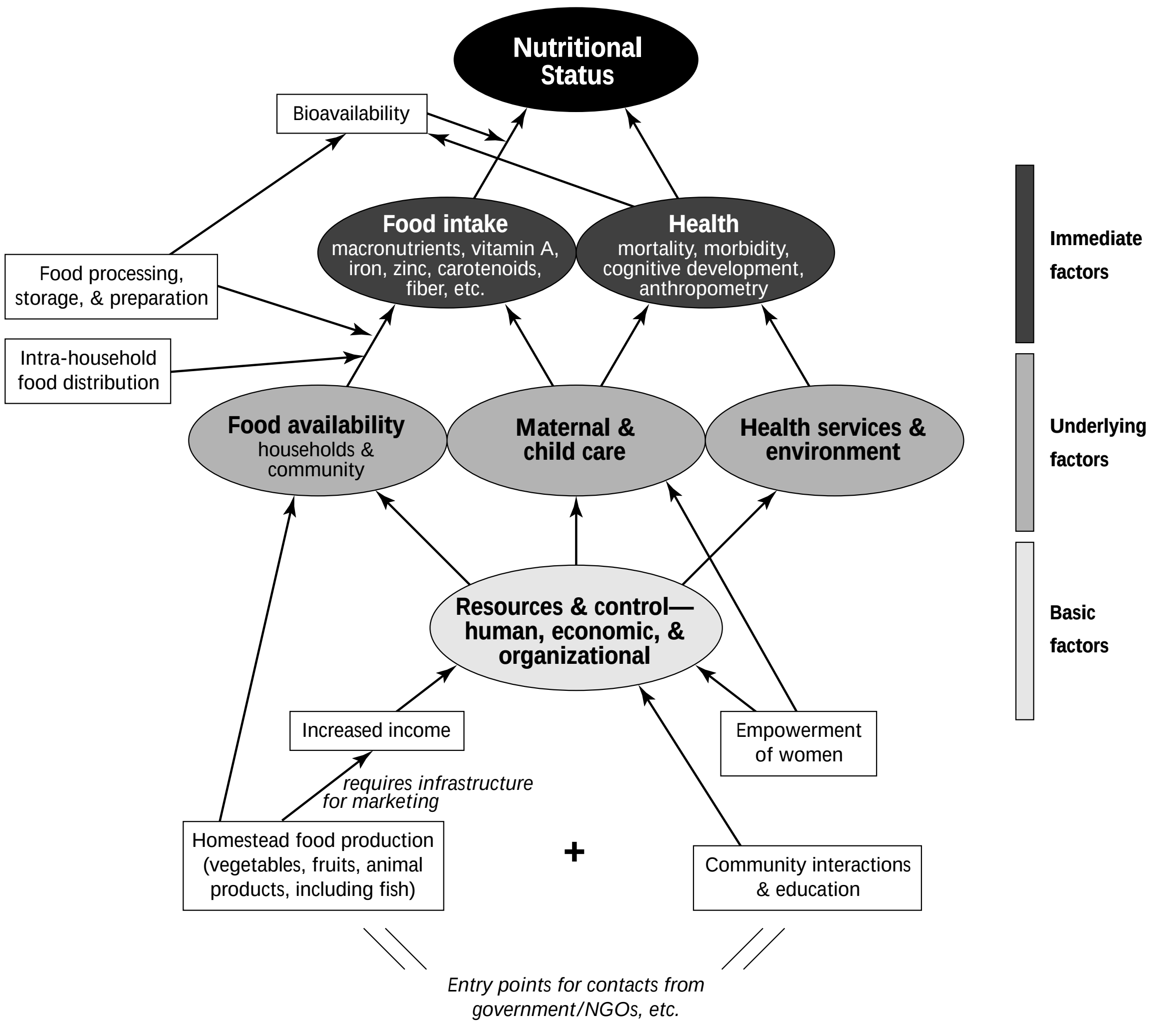

FIG. 1. Conceptual framework of causes of vitamin A deficiency (reprinted from ref. 5)

ing this are diverse and direct as well as indirect. For example, homestead food production can increase food availability at the community and household levels, which, together with care factors, can improve access to food and therefore directly increase dietary vitamin A intake. Indirectly, because homestead food production is mainly a women's activity, it can lead to empowerment of women, which may result in an increase of the household's resources that are spent on food and health care.

The framework also shows that there are many factors that could confound the anticipated impact of a food-based programme on nutritional status. Food-based approaches are implemented on top of prevailing practices of food preparation and food consumption, in addition to other health interventions, and in certain circumstances, such as by households of a certain socio-economic status and in a given set of agricultural conditions. Therefore, it is generally very difficult to identify whether and to what extent a change of nutritional status or health can be attributed to the food-based intervention itself. For example, among subjects with poor health, the impact of a food-based programme may seem limited, because recurrent illness negatively affects nutritional status and therefore counteracts a possible positive impact of the increased intake of micronutrient-rich foods on nutritional status. Thus, the broader impact of food-based approaches is an advantage, but it complicates their evaluation.

Evaluating impact on nutritional status

In order to appropriately evaluate the impact of food-based programmes, the answers to the following three questions are especially important: Does the food-based programme result in a change of food consumption by the target population? To what extent can increased consumption of, in particular, micronutrient-rich foods improve nutritional status or health? What is the evidence for, and the magnitude of, the impact of the food-based programme on nutritional status and health?

Many projects for increasing the intake of vitamin A–rich foods have been implemented. Most [9–11], but not all [12], of them were successful in increasing the production, consumption, or both of vegetables, fruits, or both (the first question above). Although several smaller studies have been conducted to answer the second question (see the following section), only a very few food-based programmes have been evaluated for their impact on health or nutritional status (the third question), for several reasons. First, usually only a small part of a programme's budget is allocated to its evaluation. Second, demonstrating an impact on food production or consumption is often regarded as sufficient evidence for a programme's success, partly because it is assumed that these will inevitably lead to the improvement of nutritional status and health. Third, the population targeted by a programme may be too small to allow for an evaluation of a change in the prevalence of nutritional deficiencies or morbidity.

Intervention studies

The key issue with respect to the impact of food-based programmes on vitamin A status is the relationship between the consumption of particular vitamin A–rich foods and vitamin A status (the second question above). This issue has been the topic of several intervention studies [1–3], and it has recently been concluded that the amount of dietary β-carotene that is nutritionally equivalent to 1 μg of dietary retinol ranges from 2 to 26 μg [13], which is a much wider range than the generally used estimate of 6 μg [14]. For dark-green leafy vegetables, the equivalent may be around 20 to 25 μg (or 20% to 30% as effective as assumed), whereas for fruits it may be around 10 to 15 μg (or 40% to 60% as effective as assumed) [1].

The vitamin A activity of foods depends on the content of retinol and provitamin A carotenoids, as well as on their bioavailability and bioconversion, which are determined by a large variety of food- and host-related factors and their interaction [2, 15]. Food-related factors include the matrix in which the carotenoids are incorporated, the type and amount of fibre, the presence of other carotenoids, the species of carotenoids, and molecular linkage. Some of these factors are intrinsic to the food, whereas others can be modified by preparation methods [16, 17]. In intervention studies, such preparation methods can be taken into account by preparing foods in a certain way. In evaluations, it is important to know what preparation methods are generally used by the population. In programmes, knowledge about more or less favourable preparation methods can be translated into specific messages for nutrition education.

Host-related factors can be split into two types: those that can be affected by intervention, which include parasitic infestation, gastric acidity, malabsorption syndromes, illness, and nutrient status, and those that are unchangeable, such as age, sex, pregnancy, and genetics. In intervention studies, host-related factors are usually controlled by involving only a particular group, for example a specific age group, and by intervening in order to have a relatively homogeneous group of subjects, for example, by deworming and by only including apparently healthy subjects. Therefore, conclusions are limited to the particular group that was selected for the intervention and under the particular (modified) circumstances. In programme evaluations, the host-related factors are generally not controlled, and when information is collected about these factors, they can be studied better and the results of evaluations can therefore differ from the results of intervention studies. In programmes, host-related factors can be taken into account by targeting specific groups as well as by particular confounding interventions for optimizing carotene bioavailability, such as deworming.

Thus, although intervention studies can elucidate the relationship between the consumption of particular foods and vitamin A status, their limitation is that the number of confounding factors that can be taken into account is limited. Such factors, however, may be relatively important for the impact of a particular food-based programme in a particular target group. Therefore, the design of food-based programmes can be based on intervention studies, but their impact has to be evaluated separately because of the many factors that play a role. Also, only programme evaluations can reveal the impact of a particular intervention relative to that of another intervention, for example, the impact of food-based programmes relative to the impact of distribution of vitamin A capsules.

In-depth analysis of cross-sectional and intervention studies

Comparison of the distribution of an indicator of nutritional status, such as serum retinol concentration, among different subgroups of a population [18, 19] or among treatment groups of an intervention study, can be used to generate hypotheses about the existence of particular subgroups that could respond differently to an increased consumption of particular foods. For example, such analyses have generated the hypothesis that among people who suffer from relatively severe parasitic infestation, an increased consumption of vegetables does not result in an improvement of vitamin A status, whereas an increased consumption of carotene-rich fruits or retinol-rich foods does improve vitamin A status.

Whereas Jalal et al. have shown that heavy *Ascaris* infestation has a large impact on carotene bioavailability or bioconversion [20], the existence of a differential impact depending on the food source of the carotenoids would have even further-reaching implications for the choice of strategies for combating vitamin A deficiency. That is, in populations where the prevalence of parasitic infestation is high, treatment of such infections should be of highest priority, because they may limit, or even inhibit, the utilization of carotenoids from vegetables.

It was through the in-depth analysis of cross-sectional data that the possible existence of subgroups was discovered [19], and in-depth analysis of intervention data led to the formulation of the hypothesis about which factor could underlie this division in subgroups. Because the sample size of the intervention study was not large enough to confirm the relationship with statistical significance, the hypothesis that was founded should now be tested.

Programme evaluations

Although intervention studies and in-depth analyses of such data can be used to study particular relationships shown in the conceptual framework, specific evaluations are necessary to assess the impact of a particular food-based programme. In principle, any evaluation of a food-based programme should take into account as many factors of the conceptual framework as possible, and the design of such an evaluation can vary. Below, we will discuss three impact evaluations of food-based programmes.

One of the first food-based programmes that was evaluated for its impact on consumption of vitamin A–rich foods as well as on vitamin A status was the ivy gourd programme in Thailand [10]. It was found that the programme markedly increased production and consumption of ivy gourd, whereas the effects on vitamin A status were inconclusive.

Evidence for an impact on vitamin A status was found for the social marketing campaign of eggs and dark-green leafy vegetables that was conducted in Central Java, Indonesia, in 1996 [21]. Nutrition surveillance data, which were collected every three months and each time from newly selected households, provided the evidence. It was found that the campaign's messages were noticed, and that within a year after the start of the campaign, the population's consumption of eggs increased, the consumption of vegetables increased, vitamin A intake increased, and vitamin A status improved. Most importantly, vitamin A status was related to the consumption of eggs as well as to vitamin A intake when receipt of vitamin A capsules and socio-economic status were controlled for [21]. In this case, the simultaneous changes in all the components affected by the campaign, in combination with the relationship among them, provided the necessary evidence that the social marketing campaign for vitamin A–rich foods resulted in an improvement in vitamin A status. Previously, analysis of data from one round of the nutrition surveillance system had shown that the serum retinol concentration of mothers was related to vitamin A intake from plant foods as well as from retinol-rich foods, to home gardening, and to socio-economic status [22]. The latter two variables were mainly indicators of longer-term intake of plant and retinol-rich foods, respectively. Thus, those results already showed that it was likely that home gardening played a role in maintaining vitamin A status in this population.

In Bangladesh Helen Keller International started a nationwide home gardening programme in 1993, which aimed at strengthening and expanding the existing practice of growing vegetables and fruits near the house

[11]. Data collected by the Bangladesh national vitamin A survey conducted in 1997–1998 among mothers and children under five years old in more than 24,000 rural households were then used to answer the question whether homestead gardening in Bangladesh reduces the risk of vitamin A deficiency.

It was found that among children aged 12 to 59 months who had not received a vitamin A capsule in the six months prior to the survey, the risk of night-blindness was lower when their house had a homestead garden [23]. Among children of households with a home garden, the risk of night-blindness was reduced less by receipt of a vitamin A capsule than among children of households without a home garden. This indicates that children of households without a home garden were most in need of the capsule. The underlying explanation for this would be that children of households with a home garden had a higher vitamin A status, probably because of a higher intake, lower morbidity, or both, and therefore a lower requirement for vitamin A. The analyses were controlled for other factors, such as morbidity in the week preceding the interview, socio-economic status, and vitamin A intake on the day preceding the interview [23]. Thus, the evaluation using the national survey data showed that among children in rural Bangladesh, both the vitamin A capsule and the vegetables from a homestead garden contributed to reducing the risk of vitamin A deficiency. For other target groups that are not eligible to receive a vitamin A capsule, homestead gardening is likely to be the most important strategy for reducing the risk of vitamin A deficiency.

Impact is situation-specific

The impact of a strategy depends not only on the target group but also on local circumstances. Whereas the impact of vitamin A capsules mainly varies with the need for vitamin A, the impact of food-based approaches can vary even more widely between regions, because it depends very much on the particular approach as well as on the circumstances in which it is implemented. It is, for example, possible that in rural Bangladesh, where there is a large gap between the need for vitamin A and its intake, home gardening has a relatively good impact on vitamin A status, whereas in other places, where the difference between need and intake is smaller, the impact is less. The impact may depend both on the amount of vitamin A obtained and on the difference made by this amount in terms of reduction of the risk of night-blindness. Whereas a much smaller absolute amount of animal foods, fortified foods, palm oil, or breastmilk would be needed to achieve an impact, an increased intake of vitamin A–rich plant foods can still make an important contribution for a particular target group in a particular situation.

The examples described above concerning the impact of a social marketing campaign for consumption of eggs and dark-green leafy vegetables in Indonesia and the reduced risk of vitamin A deficiency associated with home gardening in Bangladesh show that food-based approaches can contribute to reducing vitamin A deficiency.

Assessing changes before and after the start of a programme

The most straightforward way of showing an impact of a food-based programme is to assess changes in the intervention population before the introduction of the programme and after 12 to 24 months of conducting the programme, and to compare them with changes in a non-intervention community. However, finding a non-intervention community that is comparable enough can be very difficult. For the evaluation of the social marketing campaign in Central Java, another approach was chosen. Data from the nutrition surveillance system, which were collected every 3 months for 15 months, were used to assess changes in different components of the conceptual framework. Their simultaneous changes and the relationship among them indicated that the programme had been effective in increasing vitamin A intake and status [21].

Cross-sectional comparison of people who were or were not subject to the intervention

The strategy chosen for assessing the impact of home gardening in Bangladesh was a comparison of the risk of vitamin A deficiency among members of households with and without homestead gardens, while confounding factors were controlled for [23]. Controlling for confounding factors is especially important in this type of analysis, because such factors may obscure, reduce, or increase the apparent risk associated with the food-based activity. Among children, it was important not to just include vitamin A capsules as a confounder in the analysis of the impact of home gardening, but to analyse the impact of vitamin A capsules separately for children of households with and without a homestead garden, and the impact of home gardening separately for children who received and those who did not receive a vitamin A capsule.

For the Bangladesh homestead gardening programme, collecting and analyzing cross-sectional data was probably the best way to assess its impact on reducing the risk of vitamin A deficiency, for the following reasons. First, it is difficult to find good control communities for a comparison of subjects in communities where the home gardening programme was implemented and subjects in communities where it was not implemented, because home gardening is a common practice everywhere. Second, because night-blindness, which has a relatively low prevalence (0.3%–5%), was chosen as the primary indicator of vitamin A deficiency and its consequences, a large number of households had to be included in the evaluation, especially because the proportion of control subjects—those who did not have a homestead garden and did not receive a vitamin A capsule—was relatively low.

Other health effects of food-based programmes

Although we have focused on food-based approaches and vitamin A deficiency, it is known that increased consumption of vegetables and fruits is also associated with decreased risk of cancer and cardiovascular disease [24]. The risk of diarrhoea among women in Bangladesh [25] and the risk of mortality among children in Sudan [26] were lower in subjects with higher vitamin A intake from plant foods. This finding emphasizes the need for identifying different outcome indicators and purposes of a food-based programme.

Conclusions

In order to develop food-based approaches into a sound and well-recognized strategy for combating micronutrient deficiencies, with appropriate appreciation of their possible impact as well as of their limitations, food-based programmes have to be evaluated for their impact on nutritional status or health. This paper has suggested ways of doing this, by using a conceptual framework for designing the programme and evaluating its impact, further studying the relationship between the consumption of particular foods and nutritional status, and assessing the contribution of a food-based programme to reducing the risk of vitamin A deficiency relative to other programmes. The fact that this paper only discusses two programmes for which the impact of food-based programmes was evaluated illustrates the urgent need for discussion of this topic and for more examples.

References

1. de Pee S, West CE, Permaesih D, Martuti S, Muhilal, Hautvast JGAJ. Orange fruit is more effective than are dark-green leafy vegetables in increasing serum concentrations of retinol and β-carotene in schoolchildren in Indonesia. Am J Clin Nutr 1998;68:1058–67.
2. de Pee S, West CE. Dietary carotenoids and their role in combating vitamin A deficiency: a review of the literature. Eur J Clin Nutr 1996;50(Suppl 3):S38–S53.
3. Khan NC, West CE, de Pee S, Khoi HH. Comparison of the effectiveness of carotenoids from dark-green leafy vegetables and yellow and orange fruits in improving vitamin A status of breastfeeding women in Vietnam. Report of the XVIII International vitamin A consultative group meeting. Washington, DC: International Life Sciences Institute, 1997.
4. Johnsson U. Towards an improved strategy for nutrition surveillance. Food Nutr Bull 1995;16:102–11.
5. Bloem MW, de Pee S, Darnton-Hill I. New issues in developing effective approaches for the prevention and control of vitamin A deficiency. Food Nutr Bull 1998; 19:137–48.
6. Soleri D, Cleveland DA. Household garden as a development strategy. Hum Org 1987;46:259–70.
7. Solomons NW, Bulux J. Identification and production of local carotene-rich foods to combat vitamin A deficiency. Eur J Clin Nutr 1997;51:S39–45.
8. Cox DN, Rajusuriya SV, Soysa PE, Gladwin J, Ashworth A. Problems encountered in the community-based production of leaf concentrate as a supplement for pre-school children in Sri Lanka. Int J Food Sci Nutr 1993;44:123–32.
9. Leemon M, Samman S. A food-based systems approach to improve the nutritional status of Australian Aborigines: a focus on zinc. Ecol Food Nutr 1999;37:523–55.
10. Smitasiri S. Nutri-action analysis. Going beyond good people and adequate resources. Bangkok, Thailand: Amarin Printing and Publishing Public Company, 1994.
11. Talukder A, Kiess L, Huq N, de Pee S, Darnton-Hill I, Bloem MW. Increasing the production and consumption of vitamin A–rich fruits and vegetables: lessons learned in taking the Bangladesh homestead gardening programme to a national scale. Food Nutr Bull 2000; 21:165–72.
12. Brun T, Reynaud J, Chevassus-Agnes S. Food and nutritional impact of one home garden project in Senegal. Ecol Food Nutr 1989;23:91–108.
13. International Vitamin A Consultative Group. The bioavailability of dietary carotenoids: current concepts. Washington, DC: International Life Sciences Institute, 1991.
14. FAO/WHO. Requirements of vitamin A, iron, folate and vitamin B_{12}. Report of a joint FAO/WHO expert consultation. FAO Food and Nutrition Series No. 23. Rome: Food and Agriculture Organization, 1988.
15. Castenmiller JJM, West CE. Bioavailability and bioconversion of carotenoids. Annu Rev Nutr 1998;18:19–38.
16. Van het Hof K, Tijburg LBM, Pietrzik K, Weststrate JA. Influence of feeding different vegetables on plasma levels of carotenoids, folate and vitamin C. Effect of disruption of the vegetable matrix. Br J Nutr 1999;83:203–12.
17. Castenmiller JJM, West CE, Linssen JPH, Van het Hof KH, Voragen AGJ. The food matrix of spinach is a limiting factor in determining the bioavailability of β-carotene and to a lesser extent of lutein in humans. J Nutr 1999;129:349–55.
18. Yip R, Stoltzfus RJ, Simmons WK. Assessment of the prevalence and the nature of iron deficiency for populations: the utility of comparing haemoglobin distribu-

tions. In: Hallberg L, Asp N, eds. Iron nutrition in health and disease. London: John Libbey, 1996:31–48.
19. de Pee S, Bloem MW, Tjiong R, Martini E, Satoto, Gorstein J, Shrimpton R, Muhilal. Who has a high vitamin A intake from plant foods, but a low serum retinol concentration? Data from women in Indonesia. Eur J Clin Nutr 1999;53:288–97.
20. Jalal F, Nesheim M, Agus Z, Sanjur D, Habicht JP. Serum retinol concentrations in children are affected by food sources of β-carotene, fat intake, and anthelmintic drug treatment. Am J Clin Nutr 1998;68:623–9.
21. de Pee S, Bloem MW, Satoto, Yip R, Sukaton A, Tjiong R, Shrimpton R, Muhilal, Kodyat B. Impact of social marketing campaign promoting dark-green leafy vegetables and eggs in Central Java, Indonesia. Int J Vitam Nutr Res 1998;68:389–98.
22. de Pee S, Bloem MW, Gorstein J, Sari M, Satoto, Yip R, Shrimpton R, Muhilal. Reappraisal of the role of vegetables for vitamin A status of mothers in Central-Java, Indonesia. Am J Clin Nutr 1998;68:1068–74.
23. Kiess L, Bloem MW, de Pee S, Hye A, Khan T, Talukder A, Huq N, Haq M, Ali M. Bangladesh: xerophthalmia free. The result of an effective vitamin A capsule program and homestead gardening. In: American Public Health Association 126th Annual Meeting Report. Washington, DC: American Public Health Association, 1998:361 (Abstract).
24. Kushi LH, Lenart EB, Willet WC. Health implications of Mediterranean diets in light of contemporary knowledge. 1. Plant foods and dairy products. Am J Clin Nutr 1995;61(Suppl):1407–15.
25. Bloem MW, Huq N, Gorstein J, Burger S, Kahn T, Islam N, Baker S, Davidson F. Does the production of dark-green leafy vegetables and fruits play a role in the etiology of maternal nightblindness, diarrhea and malnutrition in Bangladesh? XVII International Vitamin A Consultative Group Meeting Report. Washington, DC: Nutrition Foundation, 1996.
26. Fawzi WW, Herrera MG, Willet WC, Nestel P, El Amin A, Lipsitz S, Mohamed KA. Dietary vitamin A intake and the risk of mortality among children. Am J Clin Nutr 1994;59:401–8.

Strengths and weaknesses of the food fortification programme for the elimination of vitamin A deficiency in the Philippines

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Abstract

The strengths and weaknesses of the food fortification programme for the elimination of vitamin A deficiency in the Philippines were identified based on availability of supporting data, fortification vehicles, fortification technology, government action, and support from various sectors. The programme has strengths in all aspects. Available data on the prevalence of vitamin A deficiency and vitamin A intake, recommended dietary allowances, and guidelines on fortification of foods were used in the development of the programme. The vehicles are widely consumed and centrally processed. The fortificants used were suitable to the specific vehicles. The efficacy of vitamin A–fortified margarine and pandesal bread has been proven. The development of a strategic plan for food fortification, the formulation of fortification legislation, and the implementation of the Sangkap Pinoy Seal *programme have been supported by government action at the executive and legislative levels. The food industry has provided support in the establishment of the fortification technology. Non-governmental and international agencies, academia, and the media continue to provide assistance in the implementation of the programme. One of the weaknesses of the programme is that there is no clear policy on food fortification. The programme remains a component of the Plan of Action for Nutrition and the National Micronutrient Operations Plan. The* Sangkap Pinoy Seal *programme, which encourages the fortification of any food product, has caused a proliferation of fortified non-staple foods in the market. Foreign exchange continues to affect the sustainability of the programme. The effectiveness of other fortified foods still needs to be determined. The programme, with all its strengths, shows great promise for sustainability. The weaknesses of the programme should, however, be addressed urgently by all concerned sectors to meet the programme's objectives.*

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Introduction

Vitamin A deficiency has been a consistent public health problem in the Philippines for the past two decades. The latest (1993) national nutrition survey conducted by the Food and Nutrition Research Institute showed that the prevalence of deficient to low serum retinol levels among six-month- to six-year-old children was 35.5%. Subclinical vitamin A deficiency among pre-school children was of public health significance in 11 out of 15 regions of the country [1].

A major contributory cause of vitamin A deficiency is inadequate intake of vitamin A. The 1993 survey revealed that the mean one-day per capita intake of vitamin A among rural inhabitants and among households in the lowest income quartile met only 74% and 64% of the recommended dietary allowance (RDA), respectively. This is supported by a food consumption study among 600 depressed households in three rural areas and one urban area that showed one-day vitamin A intake adequacy of 73% among pre-school children, 45% among pregnant women, and 28% among lactating women [2].

In response to the global call to end hunger and reduce all forms of malnutrition, the Philippine Plan of Action for Nutrition, the country's master plan for achieving nutritional adequacy by the year 2000, was formulated [3]. The plan aims to address malnutrition through five impact programmes: food security, micronutrient supplementation and food fortification, credit assistance for livelihood, nutrition education, and food assistance.

Food fortification—a food-based approach—is generally recognized as the least costly and most effective way of controlling dietary micronutrient deficiencies [4–6]. Its objective is to provide safe fortification of commonly consumed foods (such as rice, margarine, sugar, salt, oil, and flour) with essential micronutrients, especially vitamin A, iron, and iodine, and to make these accessible to the population [7].

This paper presents the strengths and weaknesses of the fortification programme for the prevention of vitamin A deficiency in the Philippines through a review of past and present efforts in the vitamin A fortification of foods. Specifically, the strengths and weaknesses were identified based on the availability of supporting data, fortification vehicles, fortification technology, government action, and the support of industry, multimedia, non-governmental organizations, international agencies, and academia.

Past efforts

In the Philippines food products were fortified with vitamin A long before the formulation of the Philippine Plan of Action for Nutrition in 1993. Monosodium glutamate (MSG) and Nutripak were fortified with vitamin A in the 1970s, and margarine in 1992.

Fortification of MSG

In the early 1970s, a research project to study the fortification of MSG with vitamin A was conducted in Cebu, Philippines. The was a joint project of the Cebu Institute of Medicine, the International Nutrition Program of Cornell University, the Nutrition Center of the Philippines, and Union Chemicals, Manila (a subsidiary of the Ajinomoto company in Japan). The MSG fortification was part of a study to compare the relative effectiveness and cost of three interventions for the control of xerophthalmia: MSG fortification with vitamin A, public health and horticulture interventions, and the provision of high-dose vitamin A capsules to all children every six months [8].

MSG was considered a potential fortification vehicle because it is widely consumed (children in 98% of households consume the product at least once a week), centrally produced by only two manufacturers in the Philippines (one of which controls 90% of the market), and affordable.

For the study, MSG was fortified with vitamin A palmitate type 250 SD (spray-dried). Because of segregation and caking, however, this was replaced with vitamin A acetate type 325L, which has a similar particle size to that of MSG. One MSG packet weighing 2.2 g provided 15,000 IU of vitamin A [9].

After about 24 months of consumption of vitamin A–fortified MSG, an increase in mean serum retinol level and a reduction in xerophthalmia was observed among the children. The public health and horticultural interventions and the high-dose capsules did not have significant effects on serum retinol levels, although the high-dose capsules significantly reduced xerophthalmia [5]. Likewise, when the trial was expanded to three other provinces to test normal market channels, a significant improvement in the serum retinol level of the target groups was seen.

Commercial-scale expansion of the fortification of MSG with vitamin A was never realized because of a technological problem, the change in the colour of MSG from pure crystalline white to yellowish after fortification. The manufacturer decided against fortifying MSG on a mass scale, despite its proven cost-effectiveness and sustainability and the moral justification that it was effective in improving vitamin A status [5]. The selling price of MSG could be maintained by reducing the amount of MSG per packet, whereas the added vitamin A replaces the decreased amount to offset the fortificant cost.

The fortification of MSG with vitamin A raised some objections from the medical community because of the controversy regarding its safety as a food seasoning. However, the World Health Organization, the Food and Agriculture Organization, and the US Food and Drug Administration have confirmed that MSG is a generally recognized as safe (GRAS) food additive [10].

Fortified processed weaning food

In the late 1970s, the Nutrition Center of the Philippines embarked on the formulation, production, and marketing of Nutripak, an energy- and protein-rich complementary food for infants and a supplementary food for underweight pre-school children. Nutripak is a rice-based multimix product composed of either green gram or skimmed milk (as a protein source), vegetable oil (as an added energy source), and cocoa powder or green gram. Shredded fish and vegetables may be added to the green gram–flavoured Nutripak during cooking. Prior to the Nutripak, there were no locally produced and sold vitamin A–fortified processed weaning or supplementary foods for infants and preschoolers.

Nutripak was consumed by 11% of the households surveyed during the 1982 nationwide nutrition survey [11]. A field trial in 1983 showed a significant reduction in the number of moderately and severely malnourished children fed with Nutripak [12].

Presently, Nutripak comes in six varieties with the new name Nutripak Plus. The *ginatan* (rice mix with dried banana and dried gabi) and the raisin and nut varieties include a rice mix, a flavour pack containing vitamin A–fortified sugar, and a coconut powder pack. The beef and chicken varieties contain a rice mix, a vitamin A–fortified vegetable oil pack, and a flavour pack containing either dried carrots (for beef) or dried saffron flowers (for chicken). The *mongo* and *champorado* (rice gruel with cocoa) varieties have a rice-flavoured mix and a vitamin A–fortified vegetable oil pack. Each 100-g pack meets at least 25% of the energy RDA, 5% of the protein RDA, and 33% of the vitamin A RDA for pre-schoolers. The price of a pack ranges from P9.50 to P10.35 (US$0.24 to 0.26).

Nutripak Plus products are marketed by the Philippine Nutri-Foods Corporation, a subsidiary of the

Nutrition Center of the Philippines. The products are used for feeding programmes by health, social welfare, and private agencies in Metro Manila and selected regions. The government also uses Nutripak Plus as a relief food for children affected by calamities. The Philippine Nutri-Foods Corporation intends to expand the marketing of Nutripak Plus in village variety stores and public markets in the community.

Fortification of margarine

The fortification of margarine (Star brand) in 1992 with adequate amounts of vitamin A and other nutrients was a significant decision by its manufacturer, Procter & Gamble Philippines [13]. This coconut oil–based, shelf-stable, non-refrigerated margarine has been popular in the Philippines since 1931. It is used as a spread on bread, a topping for rice, and an ingredient for cooking. A 1988 market survey found that the margarine was consumed by 94% of the population [14].

For the stability study and efficacy trial, the vitamin A content of the margarine was increased from 131 retinol equivalents (RE) to 431 RE per 15-g serving. The 431 RE per serving meets 115% of the RDA for three- to six-year-old children. Each serving also contains 3.0 mg of thiamine, 50 μg of cholecalciferol, and 326 μg of β-carotene as a colourant. The increase of the vitamin A content to a more substantial level was in response to the national micronutrient initiative. The added cost of fortification was P0.16 (equivalent to US$0.004 at a peso–dollar exchange rate of P39=US$1) per 100 g of margarine.

The stability study showed more than 50% vitamin A retention in the margarine after eight months of storage. At least 80% of the vitamin A was recovered after cooking with the margarine, reflecting good thermal stability [15, 16]. In 1993 the Nutrition Center of the Philippines conducted a controlled field trial among three- to six-year-old rural children to determine the effect of consuming vitamin A–fortified margarine daily for six months. The results showed a significant increase in the mean serum retinol level as well as a 60% reduction in the prevalence of low serum retinol [16].

After the successful trial and on the basis of the recommendation of the Nutrition Center of the Philippines, the manufacturer developed the micro-nutripack, a new packaging size containing 15 g of the fortified margarine. This pack, which costs only P2.00 (US$0.05), was designed to allow people in lower-income groups to buy the product. The manufacturer also embarked on a multimedia social marketing campaign to inform the public of the higher vitamin A fortification of the margarine [13, 14, 16].

The margarine was awarded a stamp of recognition from the Department of Health. The words "accepted by the Department of Health" were to be placed on the label of the product together with the testimonial in fine print "the only margarine clinically tested by the Nutrition Center of the Philippines." From this initial stamp evolved the *Sangkap Pinoy* (Filipino or indigenous ingredients) seal, a mark of recognition from the government of a properly fortified, high-quality food product. During the official launching of the *Sangkap Pinoy* Seal programme in 1996, margarine was among the first three products to carry the seal.

Practically no technological problems were encountered in the fortification of the margarine, from its formulation with vitamin A, stability tests, and successful efficacy trial to its full distribution through normal market channels. As in other countries, the Philippine experience in the fortification of margarine with vitamin A shows that even in the absence of legislation or regulations, food manufacturers are often capable of taking appropriate action to fortify processed foods with micronutrients and sustain the whole effort [4]. The fortification of margarine is unique in the sense that after advocacy, the manufacturer decided upon, initiated, and implemented the effort.

Recent efforts

From 1995 to 1997, wheat flour, sugar, and cooking oil were fortified with vitamin A as a component of the food fortification programme of the Philippine Plan of Action for Nutrition.

Fortification of wheat flour

Wheat flour meets many of the criteria for food fortification, such as wide consumption by the population and centralized processing. A food consumption survey showed that wheat flour products in the form of bread were consumed by 91% of households [2]. The import of wheat flour rose from 1.3 metric tons in 1989 to 2.1 metric tons in 1994. About 60% of this wheat is the hard flour type, which is used for the preparation of pandesal bread (33%), loaf bread (25%), rolls (20%), and noodles (18%). Wheat flour is produced by only 14 millers, 7 of which are in Metro Manila, 2 in Luzon, 3 in the Visayas, and 2 in Mindanao. Their strategic locations allow an adequate supply of wheat flour across all regions in the country [17].

As an initial step to implement the wheat flour fortification programme, the National Nutrition Council, the Department of Health, and the Nutrition Center of the Philippines met with the Philippine Association of Flour Millers and the Chamber of Philippine Flour Millers. The objective of the meeting was to inform the millers of the micronutrient deficiencies in the country and the various programmes to alleviate them. The fortification of wheat flour to solve vitamin A deficiency was emphasized. The millers raised their concerns about the increased cost of fortification and the sensory changes due to the fortification of flour with vitamin A [17]. To address these concerns, a feasibility study was conducted by the Nutrition Center of the Philippines with the participation of two millers and in collaboration with the Food Development Center, Roche Philippines, and international agencies.

The study showed that about 80% of the vitamin A added was retained in the flour and baked pandesal (the most popular bread among Filipinos) over a period of one month [17]. In the Philippines, flour is not stored for more than one month. There were no significant changes in the colour and odour of the flour or in the flavour of the bread. The added cost of the fortificant per kilogram of flour and one 30-g piece of pandesal is P0.088 (US$0.0022) and P0.0017 (US$0.00004), respectively, though the cost of fortificant is about P88.00 (US$2.26) per metric ton. To resolve this issue, the National Nutrition Council began a series of consultative meetings with the millers and bakers [18–20].

The bakers agreed to absorb the cost of the fortificant by buying vitamin A–fortified flour at an increased price. They also agreed to share the cost of publishing and disseminating advertisements for fortified pandesal in cooperation with the government, which likewise agreed to promote vitamin A–fortified pandesal through massive tri-media campaigns. In response to the millers' request for the establishment of a quality-assurance system in the production of fortified flour, the Nutrition Center of the Philippines and the Philippine Institute of Pure and Applied Chemistry, with funding from Opportunities for Micronutrient Interventions/US Agency for International Development (OMNI-USAID), developed an analytical method for the in-plant monitoring of vitamin A in fortified flour [21].

In 1997 the Nutrition Center of the Philippines, in collaboration with the Department of Education, Culture, and Sports, the Johns Hopkins University, and Helen Keller International, assessed the efficacy of vitamin A–fortified pandesal in improving the vitamin A status of Filipino schoolchildren. The double-blind, randomized clinical trial involved provision of a 60-g piece of fortified or non-fortified pandesal to 835 children on each school day for six months. The results showed improved vitamin A status, which was most evident from end-of-study differences in modified relative dose response, showing that the use of vitamin A–fortified pandesal halved the percentage of children with inadequate liver vitamin A stores [22].

However, despite the successful stability study and efficacy trial, not all flour millers have decided to pursue wheat flour fortification. Only four millers fortify about 20% of all hard flour produced.

Fortification of sugar

UNICEF advocated the fortification of sugar with vitamin A by sugar millers in the Philippines. Sugar is a suitable vehicle for fortification because it is widely consumed by the population and its production is limited to only a few manufacturers. It ranks sixth among the 25 most commonly consumed food items by Filipinos, with a national per capita consumption of 9 g per day [1].

UNICEF's advocacy led to a study on the fortification of sugar with vitamin A, with the Food and Nutrition Research Institute providing technical assistance to Victorias Milling Corporation, a leader in the sugar industry. An expert consultant from Guatemala, where the fortification of sugar with vitamin A has become a national programme, came to the Philippines to train technicians of the Victorias Milling Corporation.

The stability test showed that adequate vitamin A was retained in vitamin A–fortified pure refined sugar stored for six months at room temperature. More than 80% of the vitamin A was likewise retained when the fortified sugar was used in the preparation of hot coffee, citrus juice, and cake. The colour and flavour of the fortified sugar did not differ from that of unfortified sugar [23].

Vitamin A–fortified sugar was marketed in February 1997. In just a few months, however, the price of sugar in the world market plummeted and sent the already indebted Victorias Milling Corporation into further financial crisis. This halted the fortification of sugar with vitamin A before it could progress to full market scale. With the subsequent closing of four sugar mills, further fortification efforts for sugar will have to wait until the current sugar industry crisis in the Philippines is over.

Fortification of cooking oil

In 1997 the San Pablo Manufacturing Corporation, manufacturer of Minola cooking oil, developed, tested, and adopted the technology for fortifying cooking oil with vitamin A. The Food and Nutrition Research Institute and the Philippine Council for Health Research and Development provided technical assistance and funding support, respectively.

Cooking oil is an appropriate choice as a vehicle for vitamin A fortification because of the known solubility of vitamin A in oil. Furthermore, cooking oil is widely consumed by Filipinos, ranking third in the list of most commonly consumed or most frequently used food items in the Philippines. The per capita consumption of oil is 9 g per day [1].

The stability test on vitamin A–fortified cooking oil revealed that vitamin A was stable for five months to one year whether packed in yellow plastic bottles, tin cans, or clear glass bottles. The values of free fatty acids and peroxides during storage were within acceptable limits. Food products fried in fortified cooking oil and those fried in unfortified cooking oil had no significant differences in colour, flavour, or general acceptability. Vitamin A was substantially retained in fried banana, sweet potato fries, rice, and fish. A 15-g serving of oil can provide one-third of the RDA of vitamin A for an adult man [24].

Vitamin A–fortified cooking oil, which carries the *Sangkap Pinoy* seal, is now commercially available throughout the country. An efficacy trial on the vitamin A–fortified cooking oil, initiated by the Philippine Coconut Authority, will be conducted.

Strengths of the food fortification programme

Availability of supporting data

The Philippine government, through the Food and Nutrition Research Institute, has conducted a comprehensive national nutrition survey every five years since 1978. The surveys aim to assess the country's food and nutrition situation and the nutritional status of the population. The food fortification programme was able to use the data on regional and national prevalence of vitamin A deficiency, the vitamin A intake of the population, and the most commonly consumed or most frequently used food items by the population in its development.

The RDA values for Filipinos [25] developed by the Food and Nutrition Research Institute and the Bureau of Food and Drugs Guidelines on Micronutrient Fortification of Processed Foods [26] were also utilized in the formulation of the food fortification programme.

Suitable fortification vehicles and fortificants

The vehicles recommended for vitamin A fortification—margarine, wheat flour, sugar, and oil—meet most of the criteria for food fortification. These products are widely consumed by the population. This was evident in the Food and Nutrition Research Institute survey showing that pandesal (a wheat flour product), sugar, and cooking oil are included among the 25 food items most commonly consumed or most frequently used by Filipino households [1]. Moreover, these vehicles undergo centralized processing, since only a few millers or manufacturers are involved in their production.

The feasibility studies on the vitamin A–fortified products have proven successful. The vitamin A fortificants used were suitable to the specific food vehicles. The vitamin A added was substantially retained in the products immediately after fortification, during its shelf-life, and even after cooking. No organoleptic changes were observed in the fortified products compared with their non-fortified counterparts.

In addition, the efficacy of vitamin A–fortified margarine and pandesal has been proven through controlled field trials. These products were shown to be effective in improving the vitamin A status of children.

Government action

The fortification programme is supported by government action at the executive and legislative levels. In July 1998, Philippine President Joseph Estrada launched the *Sustansya Para sa Masa,* a multisectoral movement to fight malnutrition, and the *Pan de Bida* (pandesal with vitamin A) Project. The current leadership in the Department of Health has committed itself to developing a five-year strategic plan for food fortification. A Department of Health food fortification coordinating team and a food fortification task force composed of experts from the government, private sector, nongovernmental organizations, and academia will be created for this purpose.

At the legislative level, House Bill No. 5915, an act requiring the fortification of processed foods with essential micronutrients, has been introduced. This bill requires food manufacturers to fortify their processed foods with essential micronutrients. It mandates fortification of rice with iron and fortification of wheat flour, sugar, and cooking oil with vitamin A [27]. The bill is now due for a second reading in Congress, and its counterpart Senate bill has passed the third reading.

Sangkap Pinoy seal programme

The Department of Health's *Sangkap Pinoy* seal programme continues to encourage food manufacturers to market high-quality fortified food products [7]. The seal is awarded to food manufacturers who are able to meet the standards for fortifying products with vitamin A, iron, or iodine. It also makes the general public aware of the availability of fortified foods with assurance of quality and thus encourages them to consume such products. Presently, there are 22 food products with the *Sangkap Pinoy* seal. These include sardines, instant noodles, cheese, juice drinks, a chocolate drink, a weaning food, biscuits, margarine, snack foods, condiments, hot dogs, and hotcakes. A technical committee composed of experts from various government agencies regularly conducts quality-assurance and quality-control monitoring of these products.

The *Sangkap Pinoy* seal programme provides a mechanism for the government to support the private sector in marketing fortified foods and serves as a venue for regular consultation and dialogue with the industry for public–private sector partnership for food fortification.

Industry support of fortification technology

The vitamin A fortification projects that have been undertaken were supported by industry in terms of validation, development, and establishment of the technology for food fortification of the specific food items. Those who participated in the country's food fortification efforts include Union Chemicals (MSG), Procter

& Gamble Philippines (margarine), Republic Flour Mills and Morning Star Milling Corporation (wheat flour), Victorias Milling Corporation (sugar), and San Pablo Manufacturing Company (cooking oil).

Multimedia support

The Philippine multimedia have been very supportive of the fortification programme. Television and radio infomercials on vitamin A–fortified pandesal, for instance, were broadcast nationwide. Feature articles on vitamin A–fortified flour and pandesal have been published in leading newspapers and magazines. In July 1998 articles were published on the nutrition theme *"Fortified foods kainin, dagdag sustansya'y kamtin—Selyong Sangkap Pinoy hanapin"* (Eat fortified foods to meet nutrient needs—look for the *Sangkap Pinoy* seal). All these efforts amplified the advocacy activities being conducted by governmental, non-governmental, and international agencies.

Non-governmental organizations, international organizations, and academic support

Non-governmental organizations, international organizations, and the academic community continuously support the government programme on food fortification. The Nutrition Center of the Philippines, a non-profit, non-governmental organization, initiated studies on the stability and efficacy of vitamin A–fortified margarine, the fortification of wheat flour with vitamin A, and the efficacy of vitamin A–fortified pandesal. The policy of the Nutrition Center of the Philippines is to tap international and bilateral organizations, international and local non-governmental organizations, and academia for technical and financial assistance. The previous partners of the Nutrition Center of the Philippines in its fortification projects include UNICEF and USAID (international organizations); Helen Keller International and IMPACT Foundation, United Kingdom and Philippines (non-governmental organizations); and Johns Hopkins University, the Institute of Nutrition in Mahidol University, the University of the Philippines, and De La Salle University (academic institutions).

Nutrition education for store owners

In support of the food fortification programme, nutrition education among stall owners in public markets and owners of village variety stores has been integrated into the nutrition action programme in the community. The promotion of nutritious and fortified foods by educating owners of village variety stores is foreseen as an effective strategy to strengthen food security in the home and the community.

Weaknesses of the food fortification programme

Lack of clear programme policy

The Philippine food fortification programme remains a project under the Philippine Plan of Action for Nutrition [3] and the 1996–1998 National Micronutrient Operations Plan [7], while the Bureau of Food and Drugs Guidelines on Micronutrient Fortification of Processed Foods serves as reference for the *Sangkap Pinoy* seal programme [26]. A comprehensive food fortification programme, with specific policies, still needs to be developed. For instance, there are no clear programme policies regarding acceptable food items that can receive the *Sangkap Pinoy* seal, the conduct of food consumption surveys for possible definition of required fortification levels in food products, the dissemination of research results, and the sharing of developed fortification technology, among others.

The food fortification programme should have clear, specific, and well-defined policies so that all those concerned in its implementation will be guided properly. These will also assure better coordination of efforts by the government and the private sector.

Proliferation of fortified non-staple foods

The current food fortification programme requires fortification of staple foods but does not limit fortification of non-staple foods. House Bill No. 5915 states that other processed foods shall be fortified upon the recommendation of the Governing Board of the National Nutrition Council [27]. The *Sangkap Pinoy* seal can be placed on any non-staple food as long as it meets the standards set by the Department of Health. Food manufacturers and advertising agencies may take advantage of these provisions. Food products that are not selling or those that are less nutrient-dense can be properly fortified to make use of the seal. Consumers may associate the *Sangkap Pinoy* seal with a nutritious food product, although this is not always the case. Thus, non-nutritious foods with the seal may be preferred over more nutritious foods not carrying the seal.

Effect of foreign exchange

For most developing countries, foreign exchange determines the sustainability of a food fortification intervention [4]. This is exemplified by our experience in sugar fortification. Despite the proven technology, the fortification effort was hampered by the sudden instability of the manufacturing firm. This instability was due to financial difficulties within the firm, the devaluation of the peso, and the sharp fall in the world price of sugar, all of which are dependent upon foreign exchange.

Foreign exchange affects the cost of fortification, as in the case of wheat flour. In a developing country like the Philippines, where wheat has to be imported, fortification imposes a double constraint on flour millers, because foreign exchange is required for both the food vehicle and the fortificant. Therefore not all millers fortify their flour with vitamin A, in spite of the proven fortification technology, the successful efficacy trials, and the millers' entrepreneurial capacity. Bakers are willing to share the cost by buying fortified flour, even at a higher price, as long as all flour millers will fortify flour. Consumers will ultimately shoulder the cost of the fortificant, or bakers can reduce the size of pandesal baked from fortified flour. However, when not all millers fortify flour, a price differential between fortified and unfortified flour is created.

Need for efficacy trials

The purpose of conducting a controlled field trial of the fortified product is to determine its efficacy in improving the nutrient status of a target group and preventing the deleterious consequences of micronutrient deficiencies. This is the ultimate mark of a fortified food product. It is a valid basis for advertising claims that may increase the number of consumers, increase sales, and provide social and economic benefits to the manufacturer. The scientific community and the government may expand and intensify the use of the product because of its proven effectiveness.

Of the recommended vehicles for fortification, only vitamin A–fortified margarine and vitamin A–fortified wheat flour (as pandesal) have been tested through controlled field trials. All other fortified foods 0n the market, including those with the *Sangkap Pinoy* seal, have not been tested for their efficacy.

Conclusions

The food fortification programme for the elimination of vitamin A deficiency in the Philippines, with all its strengths, shows great promise for sustainability. The weaknesses of the programme should, however, be addressed urgently by all concerned sectors of society so that the objectives of the programme will be fully realized.

References

1. Food and Nutrition Research Institute. Fourth national nutrition survey Philippines, 1993. Tagig, Metro Manila: FNRI–Department of Science and Technology, 1995.
2. Florencio CA. Depressed households' intake of vitamin A and fortifiable foodstuffs. Technical Series No. 5. Manila: Department of Health-NS/UP/Helen Keller International, 1990.
3. National Nutrition Council. Philippine plan of action for nutrition 1993–1998. Makati, Metro Manila: NNC, 1994.
4. Nestel P. Food fortification in developing countries. Arlington, Va, USA: Vitamin A for Health Field Support (VITAL), 1993.
5. Solon FS, Fernandez TL, Latham MC, Popkin BM. An evaluation of strategies to control vitamin A deficiency in the Philippines. Am J Clin Nutr 1979;32:1445–53.
6. Arroyave G. Food nutrification with emphasis on the addition of micronutrients to wheat flour. Paper prepared for vitamin A field support group. Arlington, Va, USA: VITAL, 1992.
7. National Nutrition Council. The Philippine national micronutrient operations plan 1996–1998. Manila: NNC, 1997.
8. Latham MC, Solon FS. Vitamin A deficiency control in the Philippines. In: Bauernfeind JC, ed. Vitamin A deficiency and its control. Orlando, Fla, USA: Academic Press, 1986:425–43.
9. Solon FS, Latham MC, Guirriec R, Florentino RF, Williamson DF, Aguilar J. Fortification of MSG with vitamin A: the Philippine experience. Food Tech 1985; 39:71–7.
10. Department of Health Directorate of Nutrition, Helen Keller International–Indonesia. Monosodium glutamate (MSG)—What impact on health? Jakarta, Indonesia: DOH/HKI, 1986.
11. Food and Nutrition Research Institute. Second nationwide nutrition survey Philippines, 1982. Tagig, Metro Manila: FNRI–Department of Science and Technology, 1984.
12. Solon MA, de Leon E, Lopez M, Banez E. Changing nutrition related knowledge and behavior: video vans in the rural Philippines. Food Nutr Bull 1983;5:55–66.
13. Solon FS. Food fortification program development in the Philippines: problems and progress. Proc Nutr Soc India 1996;43:1–18.
14. Solon FS. A case report on the fortification of margarine with vitamin A: the Philippine experience. In: Symposium Report. Food fortification to end micronutrient malnutrition. Ottawa, Canada: Micronutrient Initiative, 1998:32–7.
15. Solon FS. History of fortification of margarine with vitamin A in the Philippines. Food Nutr Bull 1998;19:154–8.
16. Solon FS, Solon MS, Mehansho H, West KP, Sarol J, Perfecto C, Nano T, Sanchez LE, Isleta M, Wasantwisut E, Sommer A. Evaluation of the effect of vitamin A–fortified margarine on the vitamin A status of preschool Filipino children. Eur J Clin Nutr 1996;50:720–3.
17. Solon FS. The progress of wheat flour fortification with vitamin A in the Philippines. In: Symposium Report. Food fortification to end micronutrient malnutrition. Ottawa, Canada: Micronutrient Initiative, 1998:66–71.
18. National Nutrition Council. Report on the first advocacy meeting with wheat flour millers on the fortification of flour with vitamin A. Manila: NNC, 1996.

19. National Nutrition Council. Report on the first small group meeting with flour millers' and bakers' associations on the fortification of wheat flour with vitamin A. Manila: NNC, 1996.
20. National Nutrition Council. Report on the second advocacy meeting on the fortification of wheat flour with vitamin A. Manila: NNC, 1997.
21. Solon FS. Final report. Development of an analytical method for the in-plant monitoring of vitamin A in fortified flour. Manila: Nutrition Center of the Philippines, 1998.
22. Nutrition Center of the Philippines. Fortified pandesal can save many of our children. Update for Nutrition Action 1999;4:1–2.
23. Marero LM, Florentino RF, Aguinaldo AR, Capanzana MV, Saises MC. Fortification of sugar with vitamin A: technology generation and transfer. Tagig, Metro Manila: Food and Nutrition Research Institute–Department of Science and Technology, 1997.
24. Marero LM, Saises MC. Fortification of coconut cooking oil with vitamin A: technology generation and transfer. Tagig, Metro Manila: Food and Nutrition Research Institute–Department of Science and Technology, 1997.
25. 1989 RDA Committee, Food and Nutrition Research Institute. Recommended dietary allowances for Filipinos. Tagig. Metro Manila: FNRI-DOST, 1989.
26. Department of Health. Guidelines on micronutrient fortification of processed foods. Manila: DOH, 1995.
27. House of Representatives. An act requiring the fortification of processed foods with essential micronutrients and for other purposes. Manila: House Bill No. 5915, 1998.

Comments on the development of high-carotene foods with the use of biotechnology

Vinodini Reddy

Previous speakers have reviewed experiences with various dietary approaches, including horticulture and education programmes to improve vitamin A intake. There are also efforts to develop new high-carotene foods through horticulture research and biotechnology. I would like to draw your attention to recent developments in this area.

In India green leafy vegetables form a major source of vitamin A in diets of poor communities. Amaranth and spinach are among the most commonly consumed leafy vegetables. Recently, the agriculture department released a number of high-yielding varieties of amaranth for cultivation. Their main aim is to enhance farm production and income generation. Analysis of these foods by the National Institute of Nutrition revealed that some of the new varieties have a concentration of β-carotene four to six times higher than that of traditional varieties. Among other vegetables, carrots and yellow sweet potatoes have significant amounts of β-carotene. Selective propagation of such varieties will go a long way in combating vitamin A deficiency in the population.

Tomatoes are another important crop in India and other Asian countries. However, the traditional variety of tomato has little β-carotene. Recently, the Asian Vegetable Research and Development Center (AVRDC), Taiwan, has developed new strains of tomato with a high content of β-carotene. They can be grown in the dry season and are resistant to many plant diseases.

The new variety of tomato is orange and looks different from the traditional variety. Field trials are under way in Bangladesh to evaluate their acceptability by farmers and consumers.

Another new example is the high-carotene sweet potato. It has an orange colour, unlike the traditional variety. The plant is high-yielding and early maturing, which makes it a more acceptable food crop. Sweet potato is used as a staple food in some African countries and forms a major source of energy. Recently, the International Food Policy Research Institute initiated a field project in Mozambique to encourage production and consumption of this new variety for sustainable nutritional improvement, addressing macro- as well as micronutrient malnutrition.

Among vegetable oils, red palm oil is the richest source of carotenoids. Recently, scientists at Monsanto developed red canola oil using biotechnology. It is a unique blend of several carotenoids at concentrations much higher than in red palm oil. Although these oils can be used as dietary supplements, they may not be acceptable for a cooking medium because of their red colour. However, biotechnology makes it possible to modify the colour of canola oil by reducing the carotenoids to a desired level. Carotenoids supplied in oil have an advantage over vegetables and fruit because of their higher bioavailability.

Thus, there is a great potential to improve the nutritional quality of foods and augment the supply of vitamin A and other nutrients through selective plant breeding and biotechnology. This is an important complementary strategy to accelerate progress in eliminating vitamin A deficiency.

The author is the former Director of the National Institute of Nutrition in Hyderabad, India.

Mention of the names of firms and commercial products does not imply endorsement by the United Nations University.

Books received

Forum on functional food: Proceedings. Strasburg Council of Europe. 1–2 December 1998. Council of Europe Publishing, Strasburg, Germany, 1999. (ISBN 92-871-3909-1) 371 pages, paperback.

This publication contains lectures presented at a Forum on Functional Food held in Strasbourg in December 1998. It provides a comprehensive introduction to the relatively new science of functional foods, now recognized as an integral part of food science. A functional food is one that can be demonstrated to affect beneficially one or more target functions in the body beyond recognized nutritional effects in a way that improves the state of well-being and health or reduces the risk of a disease. The forum emphasized that although the importance of a balanced diet should be the main message to the consumer, functional foods as a part of such a diet, if their use is supported by scientific evidence, can be of additional benefit to health and reduce disease risks.

Preparation and use of food-based dietary guidelines. Report of a joint FAO/WHO Consultation. World Health Organization, Geneva, 1998. (ISBN 92-4 12088-5) 108 pages, paperback.

Because most people think in terms of food, not nutrition, an FAO/WHO consultation was held to draw up guidelines for good nutrition based on the foods that make up a healthful diet. After reviewing the evidence for the health impact of diet, the report outlines steps for choosing food-based strategies that will improve nutrition. It describes successive stages of reviewing relevant information, drawing up guidelines, and putting them into practice in a culturally acceptable manner. It will be useful to anyone concerned with developing dietary guidelines, nutrition educational materials for the public, and media campaigns on nutrition.

Preventing iron deficiency in women and children: Technical consensus on key issues. International Nutrition Foundation and the Micronutrient Initiative, Boston, Mass, USA, and Ottawa, Canada, 1999. (ISBN 1-894217-07-1) 60 pages, paperback.

This report is a joint effort of a group of experienced international health workers and eminent scientists who participated in a UNICEF/UNU/WHO/MI Technical Workshop designed to reach a consensus on issues that can accelerate and expand national programmes for the prevention of iron deficiency. The report reviews the causes of iron deficiency and describes the massive economic costs of the high global prevalence of iron deficiency. It emphasizes the serious consequences of iron deficiency for cognition, resistance to infections, work capacity, morbidity, and mortality. Actions to expand and accelerate programmes to prevent iron deficiency are urged. The group achieved consensus on the need for integrating multiple interventions that included food fortification, oral supplementation, communication for dietary change, and a series of related health measures, including the control of parasitic diseases causing iron loss and better spacing of children. Technical issues that have delayed programme implementation were reviewed, and a satisfactory consensus was reached on most of them. This publication is designed to raise the profile and priority for the prevention of iron deficiency among international and bilateral agencies and national governments. All concerned with the prevention of micronutrient deficiencies should request this publication, which is available without charge from the Micronutrient Initiative, c/o International Development Research Center, P.O. Box 8500, 250 Albert Street, Ottawa ON, Canada KIG 3H9, or at mi@idrc.ca.

Note for contributors

The editors of the *Food and Nutrition Bulletin* welcome contributions of relevance to its concerns (see the statement of editorial policy on the inside of the front cover). Submission of an article does not guarantee publication—which depends on the judgement of the editors and reviewers as to its relevance and quality. All potentially acceptable manuscripts are peer-reviewed. Contributors should examine recent issues of the *Bulletin* for content and style.

Language. Contributions may be in English, French, or Spanish. If French or Spanish is used, the author should submit an abstract in English if possible.

Format. Manuscripts should be typed or printed on a word processor, double-spaced, and with ample margins. Only an original typed copy or a photocopy of equivalent quality should be submitted; photocopies on thin or shiny paper are not acceptable.

When the manuscript has been prepared on a word processor, a diskette, either 3½- or 5¼-inch, should be included with the manuscript, with an indication of the disk format and the word-processing program used.

Length. Ordinarily contributions should not exceed 4,000 words.

Abstract. An abstract of not more that 150 words should be included with the manuscript, stating the purposes of the study or investigation, basic procedures (study subjects or experimental animals and observational and analytical methods), main findings (give specific data and their statistical significance if possible), and the principal conclusions. Emphasize new and important aspects of the study or observations. Do *not* include any information that is not given in the body of the article. Do not cite references or use abbreviations or acronyms in the abstract.

Tables and Figures. Tables and figures should be on separate pages. Tables should be typed or printed out double-spaced. Submit only original figures, original line drawings in India ink, or glossy photographs. Labels on the figures should be typed or professionally lettered or printed, not handwritten.

Photographs. Ideally photographic materials should be submitted in the form of black and white negatives or black and white glossy prints. Photographs will not be returned unless a specific request is made.

Units of measurement. Preferably all measurements should be expressed in metric units. If other units are used, their metric equivalents should be indicated.

Abbreviations. Please explain any abbreviations used unless they are immediately obvious.

References. References should be listed at the end of the article, also double-spaced. Unpublished papers should not be listed in references, nor should papers submitted for publication but not yet accepted.

Number references consecutively in the order in which they are first mentioned in the text. Identify references in the text and in tables and figure legends by arabic numerals enclosed in square brackets. References cited only in tables or figure legends should be numbered in accordance with the first mention of the relevant table or figure in the text. Be sure references are complete.

Reference citations should follow the format illustrated below.

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—*standard journal article* (list all authors):

1. Alvarez ML, Mikasic D, Ottenberger A, Salazar ME. Caracteristicas de familias urbanas con lactante desnutrido: un análisis critico. Arch Latinoam Nutr 1979;29:220–30.

—*corporate author:*

2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

Book or other monograph reference

—*personal author(s):*

3. Brozek J. Malnutrition and human behavior: experimental, clinical and community studies. New York: Van Nostrand Reinhold, 1985.

—*corporate author:*

4. American Medical Association, Department of Drugs. AMA drug evaluations. 3rd ed. Littleton, Mass, USA: Publishing Sciences Group, 1977.

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5. Medioni J, Boesinger E, eds. Mécanismes éthologiques de l'évolution. Paris: Masson, 1977.

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6. Barnett HG. Compatibility and compartmentalization in cultural change. In: Desai AR, ed. Essays on modernization of underdeveloped societies. Bombay: Thacker, 1971:20–35.

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Manuscript copies. The contributor should keep a duplicate copy of the manuscript. Manuscripts will not be returned unless specifically requested. Proofs will be sent to the authors only in exceptional circumstances.

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La rédaction du *Food and Nutrition Bulletin* recherche des articles traitant de sujets correspondant à ses thèmes (voir au vérso de la couverture la politique éditoriale de cette revue). La remise d'un manuscrit ne signifie pas sa publication, qui dépend de l'opinion de la rédaction et des réviseurs sur son intérêt et sa qualité. Tous les manuscrits susceptibles d'être acceptés sent révisés par des pairs. Les auteurs sent invités à se pencher sur les récents numéros du *Bulletin* pour prendre connaissance de son contenu et de son style.

Langues. Les manuscrits peuvent être rédigés en anglais, en français ou en espagnol, et dans ces deux derniers cas, l'auteur ajoutera, si possible, un résumé en anglais.

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Lorsque le manuscrit a été préparé sur une machine de traitement de texte, une disquette de 3,50 ou de 5,25 pouces devrait dans toute la mesure possible y être jointe en précisant son format et le programme utilisé.

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Résumé: Un résumé de 150 mots maximum doit accompagner le manuscrit. Il devra donner les buts de l'étude ou des recherches, les procédures de base (sujets de l'étude ou animaux expérimentaux et méthodes d'observation et d'analyse), les principaux résultats (fournir des données spécifiques et indiquer dans la mesure du possible leur importance statistique) ainsi que les principales conclusions. Veuillez mettre en relief les aspects nouveaux et importants de l'étude ou des observations. Prière de *ne pas* inclure des informations qui ne figurent pas dans le corps de l'article. Dans le résumé, ne citez aucun ouvrage de référence et n'utilisez ni abréviations ni sigles.

Tableaux et figures. Ils doivent être reportés sur des feuillets séparés. Les tableaux doivent être dactylographiés ou imprimés en double interligne. Veuillez soumettre uniquement des figures originales, des dessins à l'encre de Chine ou des photographies tirées sur papier glacé. Les labels qui apparaissent sur les figures doivent être dactylographiés ou gravé ou imprimés de manière professionnelle et non pas écrits à la main.

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Resúmenes. Se adjuntará al manuscrito un resumen que no exceda de 150 palabras, y que indicará el objetivo del estudio o investigacion, métodos básicos (individuos, animales seleccionados en experimentos y métodos de observación y análisis), descubrimientos principales (si fuera posible aportando datos específicos y su significado estadístico), y las conclusiones principales. Se enfatizarán los aspectos nuevos e importantes del estudio u observaciones. Rogamos *no* incluya informaciones que no se hayan dado en el cuerpo del artículo. En el resumen no se citarán referencias ni se usarán abreviaturas ni siglas.

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2. Committee on Enzymes of the Scandinavian Society for Clinical Chemistry and Clinical Physiology. Recommended method for the determination of gammaglutamyltransferase in blood. Scand J Clin Lab Invest 1976;36:119–25.

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4. American Medical Association, Department of Drugs. AMA drug evaluations. 3ra edición, Littleton, Mass., EE.UU.: Publishing Sciences Group, 1977.

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5. Medioni J, Boesinger E, editores, Mécanismes éthologiques de l'évolution. París: Masson, 1977.

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