

OMNI Brief 1

Can Foods Rich in Provitamin A Carotenoids Provide Adequate Vitamin A for Human Needs?

Workshop on the Bioavailability
& Bioconversion of Carotenoids

April 4-5, 1995
Washington, D.C.

Foreword

Increasing the consumption of carotenoid-rich plant foods has generally been accepted as an important long-term solution to improve vitamin A status. To date, however, the link between increased dietary intake of carotenoid-rich foods and vitamin A status is not clear. Among other issues, this has raised questions about the bioavailability and bioconversion of provitamin A carotenoids in humans and their contribution to vitamin A status, particularly in infants, preschool children, and pregnant and lactating women in developing countries.

On April 4-5, 1995, a workshop on the Bioavailability and Bioconversion of Carotenoids was conducted in Washington, DC, under the joint organization and sponsorship of The Micronutrient Initiative (MI) and the United States Agency for International Development (USAID)/Opportunities for Micronutrient Interventions (OMNI) project. Forty-five scientists, nutrition program managers, and representatives of non-governmental organizations, and international donor agencies met to address the question: Can foods rich in provitamin A carotenoids provide adequate vitamin A for human needs?

In addition, the participants: (1) identified key research questions that must be addressed for food-based vitamin A strategies to be more effective; (2) established their priority; (3) suggested experimental approaches; and (4) provided program guidance that would have the greatest relevance to populations most at-risk of clinical and subclinical vitamin A deficiency -- women, infants and children in developing countries.

USAID, through its **OMNI** project, and in cooperation with the Micronutrient Initiative, is pleased to provide the summary of those discussions as the first of an occasional series of **OMNI Briefs**. We trust that this summary and the workshop that generated it will help to identify and resolve issues critical to the formulation of research and to guide the choice and design of dietary interventions, and that women and children world-wide will benefit.

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Introduction

In many of the epidemiological, case control, cohort, and clinical trial studies reviewed as background for the workshop, deficiencies in research design and methods were noted that limit the scientific strength of any one study to definitively link food sources of provitamin A carotenoids with improved vitamin A status. Nevertheless, a positive clinical or biochemical response to provitamin A carotenoids in foods has been observed in many studies conducted among populations with evidence of vitamin A deficiency. The consensus of the participants was that carotenoid-rich fruits and vegetables provide a substantial and necessary contribution to the requirements of vitamin A and other nutrients of populations at-risk of nutrient deficiencies in developing countries and that consumption of these foods should be encouraged.

The bioavailability (absorption) and bioconversion (generation of active retinoids) of provitamin A carotenoids are influenced by a number of factors, some known and others still unknown, that relate (1) to the age and physiological state of the individual consuming food, (2) how the carotenoid is complexed within the food matrix, (3) the manner in which the food is prepared, and (4)

the nature of the meal in which it is consumed. Some of the factors can be overcome or mitigated, thereby improving provitamin A carotenoid utilization.

Additional studies are needed to more clearly elucidate the factors that influence the repletion of deficient stores and the maintenance of vitamin A adequacy from provitamin A carotenoids. This information will be important to help policy makers and program planners decide which types of carotenoid-rich fruits and vegetables should be promoted and which preparation methods should be encouraged in order to maximize the impact of dietary improvement programs on vitamin A status. This information will also enable policy makers and program planners to estimate the adequacy of increases in the consumption of provitamin A carotenoids in fruits and vegetables for those most at-risk of vitamin A deficiency, and to assess whether and under what conditions there will be a need for supplemental preformed vitamin A (retinol) from foods of animal origin, fortified foods, and/or pharmaceutical preparations in order to ensure optimal vitamin A status of at-risk populations.

Food-Related Issues

Community programs should emphasize increasing the production and consumption of locally-available carotenoid-rich foods. Food processing, storage, and preparation also have substantial effects on the content and bioavailability of carotenoids in foods. While cooking may destroy carotenoids, particularly at extremes of heat and cooking time, it also has the potential to increase carotenoid bioavailability, promoting their release from the plant matrix. Practical cooking methods that maximize retention and bioavailability of carotenoids in foods need to be identified and advocated through nutrition education and extension programs. This will depend on the strengthening of both regional and in-country capabilities to analyze the provitamin A-carotenoid content of representative samples of fruits and vegetables as they are prepared and consumed rather than as raw plants.

Although HPLC methods are considered the "gold standard" for analysis of carotenoids in foods, modern open-column chromatography can be used at a fraction of the cost of HPLC systems. However, there is a need to standardize and assess the accuracy of all carotenoid analytical methods and to make carotenoid reference standards widely available. FAO is currently developing guidelines for collection and handling of representative plant and food samples for analyses. Standardized procedures will need to be widely disseminated and training conducted to improve the reliability of analytical data in plant/food carotenoid composition tables and databases for dietary assessment and program planning.

Because of differences in food processing and preparation techniques, as well as differences in bioavailability, use of the common bioconversion ratios of 1:6 for β -carotene and 1:12 for other provitamin A carotenoids are not always appropriate for dietary assessment. Better assessment techniques of the carotenoid bioavailability in plants and prepared foods need to be developed, particularly those using in vitro methods, validated by human and other in vivo studies. These should take into account fat and other factors in the meal that may influence intestinal uptake. For the present, it may be preferable to continue to rank carotenoid bioavailability by food groups, i.e. (in order of decreasing bioavailability) red palm oil and oleoresins; yellow/orange fruits, vegetables and tubers; and dark green, leafy vegetables. In the long-term, new, acceptable cultivars of fruit and vegetable crops with greater content and bioavailability of provitamin A carotenoids may be developed through plant breeding and genetic engineering, but their impact will likely be secondary to expanding the production and consumption of presently available carotenoid-rich fruits and vegetables.

Physiology/Metabolism Issues

Parasitism and disease resulting in intestinal dysfunction may have profound effects on carotenoid uptake and bioconversion, but these have not been adequately (and quantitatively) assessed. For example, in some studies, the lack of observed improvement in vitamin A status in individuals consuming dark green, leafy vegetables may be attributable, at least in part, to concomitant infection with intestinal helminths, *Heliobacter*, or other organisms. Persistent diarrhea, lipid malabsorption, and deficiencies of vitamin A, protein, and zinc also appear to be important factors that impair provitamin A-carotenoid utilization, in addition to their effects on vitamin A metabolism and turnover. Poor health and illness also affect appetite and limit the consumption of bulky fruits and vegetables, particularly among young children. Carotenoid-rich fruits and vegetables may indeed provide sufficient vitamin A to meet physiological requirements and even replete body stores under conditions of relatively good health and hygiene. However, debilitating infections and parasitic infestations which are endemic in the tropics and subtropics both compromise carotenoid (and other nutrient) utilization and increase the individual's requirement for vitamin A. Thus, programs which seek to improve community vitamin A status through food-based interventions will be complemented and strengthened by public health measures which decrease the burden of infection and illness.

A critical research question that needs to be addressed is whether provitamin A carotenoids that are absorbed intact and are "stored" or accumulate in the body, particularly in fatty tissue, can then be converted to vitamin A. Many studies have attached "significance" to increases in serum carotenoids as a measure of bioavailability with the implication that this, in some way, is associated with improved vitamin A status. However, the extent to which these absorbed carotenoids are bioconverted to meet tissue requirements for vitamin A remains unknown. Thus, the contribution of absorbed and accumulated carotenoids to the total vitamin A pool during periodic and seasonal deficits of vitamin A in individuals with marginal-to-depleted stores needs to be assessed. Continued emphasis should be placed on programs that ensure availability of both fresh and preserved sources of vitamin A- and carotenoid-rich foods throughout the year.

High-dose vitamin A supplementation of mothers within six weeks postpartum is known to increase breast milk vitamin A and improve the vitamin A status of breastfeeding infants. Whether, and to what extent, infants can utilize provitamin A carotenoids from breast milk is, however, unknown. Thus, increasing breast milk carotenoids may be of little value if infants cannot convert them to vitamin A. Furthermore, as infants begin to consume complementary foods, it is not known to what extent they are able to extract and utilize provitamin A carotenoids in fruits and vegetables -- it cannot be assumed that absorption and bioconversion of carotenoids to vitamin A is the same in children under two years of age as it is in older children and adults.

Many of these basic questions can be addressed through the use of stable isotope techniques. Refinement of the isotope dilution method to determine total vitamin A body stores and turnover will also be critical to validate improved methods to assess vitamin A status, particularly field-applicable techniques. Plasma retinol is a relatively insensitive indicator of vitamin A status in populations that are moderately deficient or with marginal vitamin A stores. The relative-dose response (RDR) assays are more sensitive indicators of deficiency, but only when vitamin A stores are depleted below a critical level. There is, at present, no single good indicator of "marginal" vitamin A status that quantitatively measures progressive depletion or repletion of vitamin A stores. New and refined assessment techniques for vitamin A must be closely linked with physiological responses and outcomes.

Conclusion: Next Steps

The potential benefits and the factors which influence the utilization of provitamin A carotenoids in various foods and diets need to be assessed with greater rigor and more sensitive techniques. In some cases, insensitivity of existing methods to detect changes in vitamin A status, particularly in marginally deficient populations, may have resulted in failure to demonstrate beneficial effects from increased consumption of carotenoid-rich fruits and vegetables. It is critical that the ability of at-risk individuals to derive adequate vitamin A from these foods to meet immediate requirements and replenish body stores be assessed with the same rigor that has been applied in evaluating the efficacy of vitamin A supplementation.

Addressing the provitamin A-carotenoid bioavailability and bioconversion research agenda will serve to advance food-based strategies for the alleviation of vitamin A deficiency globally. Key areas of study will include: (1) food processing, storage, and preparation methods to maximize retention and bioavailability of provitamin A carotenoids; (2) standardized methods of analyzing the provitamin A carotenoid content of foods; (3) effects of parasitism and disease on provitamin A carotenoid uptake and bioconversion; (4) metabolism of circulating and “stored” provitamin A carotenoids and their contribution to the total pool of vitamin A in the body; and (5) utilization of provitamin A carotenoids in breast milk and complementary/weaning foods by infants and young children.

Information from these and other studies will assist policy makers and planners in formulating more efficacious, sustainable strategies to reduce deficiency and improve the vitamin A status of their populations. Regional, national and local policies and programs need to be optimized based on the prevalence and severity of vitamin A deficiency, cultural/dietary practices, and available resources to determine the appropriate mix of promoting production and consumption of vitamin A- and carotenoid-rich foods, vitamin A fortification of foods, and vitamin A supplementation. Research and other issues concerning provitamin A carotenoid utilization should not detract from the immediate need and opportunity to promote greater consumption of micronutrient-rich fruits and vegetables among all populations.

Acknowledgements

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OMNI (Opportunities for Micronutrient Interventions) is a five-year project funded by the Office of Health and Nutrition of the U.S. Agency for International Development (USAID) to control and prevent micronutrient deficiencies in developing countries. The project builds on long-term U.S. investment and experience in nutrition research and program operations. **OMNI** will help expand the availability of foods to communities, improve household access to and increase the consumption of micronutrient-rich foods or supplements by vulnerable individuals and communities in countries around the world.