Homestead Food Production – A Strategy to Combat Malnutrition & Poverty

HELEN KELLER INTERNATIONAL
ASIA-PACIFIC

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Foreword

Home Gardening is a key program activity for Helen Keller International (HKI) in the Asia-Pacific region. In 1988, HKI conducted a pilot Home Gardening project among 1,000 households in Bangladesh. Based on the results and experience gained from this pilot project, we then started the NGO Gardening and Nutrition Education Surveillance Project (NGNESP) in the early 1990s. Today, it has achieved nationwide coverage and reaches approximately 800,000 households throughout the country – indeed it is the largest program of its kind in the world.

When it started, the NGNESP was implemented mainly to combat vitamin A deficiency disorders. Based on new knowledge gained from the vast amount of research conducted over the last decade on the etiology of such disorders, HKI has recognized that Home Gardening needs to be broadened to Homestead Food Production – including animal husbandry and poultry raising – to be more effective and address other micronutrient deficiencies as well.

However, advocating Homestead Food Production programs remains challenging because the important question of how they affect individuals at the household level is difficult to answer. Even renowned organizations in agricultural development, such as the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD), have difficulties in showing a clear impact of such activities. Therefore, in the 12 years of implementing the NGNESP, HKI has dedicated a great deal of effort to assessing the impact of food-based approaches, which we would like to share through this publication.

This publication highlights the extensive work of HKI and of individuals working with HKI in the area of food-based approaches and the efforts to identify their different impacts. First, we review current knowledge on food-based approaches and their impact on nutritional status, health and development, with an emphasis on Homestead Food Production and social marketing of vitamin A-rich foods. These issues are discussed in the context of HKI's food-based programs in the Asia-Pacific Region. Then, we include our key articles that have brought food-based approaches such as Homestead Food Production into the mainstream of scientific and programmatic discussion. These articles highlight the extensive work conducted by HKI in Bangladesh, the important findings about the bioavailability of vitamin A from fruits and vegetables and social marketing in Indonesia, and experiences in evaluating food-based programs – which illustrates the breadth of our work in food-based approaches.

It is important to understand that while Homestead Food Production will not eliminate micronutrient deficiencies, the data generated over the years show that it can help reduce the risk of such deficiencies in a household by increasing the consumption of home-grown micronutrient-rich vegetables and fruits, increasing household income from the sale of garden produce that is used to purchase micronutrient-rich animal products, and improving household caring practices through the empowerment of women.

Foreword

Food-based approaches have much to offer. They build on existing knowledge and technologies and provide poor people the means to increase their self-sufficiency. Homestead Food Production deserves to be seen in its original context; that is, it is an activity that has been practiced for millennia, since the first humans learned to cultivate their own crops and domesticate animals for food production, and it is part of daily life in rural and peri-urban areas. It is therefore a highly sustainable and adaptable approach to breaking the cycle of malnutrition and poverty in which the world's poorest are needlessly mired. In fact, Homestead Food Production especially has a role to play when economic development is not yet at its best. The advantage of having such a program will also be that the beneficiaries can take better advantage of other health delivery systems and other interventions can link to the system. Thus, the benefits are multiple, even if the quantification of specific benefits is a real challenge.

Programmatically, our experience with the NGNESP has shown that it was possible to scale up a very small pilot study into a nationwide program and reach a high level of sustainability. Sustainability is the ultimate goal of successful program implementation, and the program's strategy of working through local NGOs and the promotion of indigenous crops have proven to be a successful formula.

The achievements of HKI's Homestead Food Production program which has, directly or indirectly, led to many of the papers included in this publication, are the product of the hard work and tireless effort of the many local and international partners with whom we have always collaborated and with whom we continue to collaborate. We have attempted the immense task of acknowledging all of these partners in the Acknowledgements section of this publication (p122). Several organizations and individuals, however, were key to the program's development and its continued existence. In particular, credit must be given to Dr. Frances Davidson (United States Agency for International Development), the Netherlands Organization for International Development Cooperation (NOVIB), Dr. Elly Leemhuis de Regt (Goverment of the Netherlands), and Dr. Robin Marsh (Asian Vegetable Research and Development Center). Additionally, we thank FAO (particularly in the region through Dr. Nandi Biplab) and IFAD for their strong advocacy of our program. I am also especially grateful to Dr. Barbara Underwood (International Union of Nutritional Sciences) and Dr. Nevin Scrimshaw (United Nations University) for their tireless advocacy to bring Homestead Food Production onto the international platform.

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Summary

Homestead food production is a worldwide practice that has existed for many centuries.[1] The main purpose of this indigenous practice is to grow food for the family and provide additional income.[2,3] A few decades ago, projects were started that aimed at improving, and sometimes also initiating, homestead gardening for the purpose of combating vitamin A deficiency disorders (VADD). Those projects focused particularly on growing and consuming dark green leafy vegetables and yellow/orange fruits. In areas where the availability of vitamin A-rich vegetables and fruits did not appear to be a constraint for increasing their consumption, social marketing campaigns were conducted in order to stimulate their consumption.

In recent years, the concept of homestead gardening has increasingly been broadened to also include the production of animal foods, for example through poultry keeping, small animal husbandry and/or fish ponds, and it is therefore called homestead food production. The main aims of homestead food production are still the production of nutritious, micronutrient-rich, foods for household consumption and the generation of additional income, but its role in women's empowerment, community mobilization, and poverty reduction are increasingly being recognized.[4]

Helen Keller International's (HKI) food-based programs

HKI's homestead food production programs, the first of which was started in the early 1990s in Bangladesh, aim to increase the production and consumption of vegetables and fruits all year round, particularly those rich in vitamin A. HKI's homestead food production programs are unique in the sense that they are implemented on a large scale (approximately 800,000 households in Bangladesh at the start of 2001) and at a very low cost (for example, US$5 per household during the first year of the HKI homestead food production project in Cambodia). This is possible because the program, known as the NGO Gardening and Nutrition Education Surveillance Project (NGNESP), is largely implemented by local non-governmental organizations (NGOs) that have integrated the support for homestead food production into their services to the community, and because homestead food production is a long existing practice in Asia. Talukder et al have described how the HKI homestead food production program in Bangladesh was started, how it was scaled up, and how it is continuously monitored in order to ensure good performance.[5]

However, we also highlight that implementation has been successful because the NGNESP is anchored in the community, both through the links with the local NGOs and the development of village nurseries. Based on the experience in Bangladesh, HKI/Asia-Pacific has now also started to promote homestead food production programs adapted to the local context in Nepal and Cambodia. Further details on the practicalities of homestead food production are presented in HKI's home gardening handbook for South Asia[6] and the Food and Agriculture Organization of the United Nations/International Life Sciences Institute guide to food-based approaches.[7]

HKI has long experience in designing and implementing social marketing campaigns in Indonesia, where fruits and vegetables are relatively easily available throughout most of the year. Initially, these campaigns focused on promoting high-dose vitamin A capsules and then later also on the consumption of vitamin A-rich foods, including both green leafy vegetables as well as eggs.

Evaluating impact of food-based programs

The aim of food-based programs is to increase the consumption and, where necessary, the production of fruits and vegetables as well as improve the nutritional status of the household members. All of these aspects should be assessed when evaluating a program. Assessing whether a program has increased production and/or consumption of fruits and vegetables is relatively straightforward, but assessing an impact on nutritional status is more complicated. In the following section, we will discuss the evidence for an impact of homestead food production on production and/ or consumption of fruits and vegetables and then discuss the evidence for an impact on nutritional status.

Impact of HKI's food-based programs on production and consumption

Regular monitoring of HKI's homestead food production programs (see Appendix 2, p20, and Round Reports from Bangladesh, Cambodia and Nepal, listed on p124) has shown that the proportion of households that practice homestead gardening increases markedly in areas where the program is introduced and that less than 5% of households discontinue homestead food production after having joined the program.

Homestead gardening practices also improve considerably over time. Improvements have been observed in the following areas: 1) An increase in the proportion of households that grow plants in one or more fixed plots rather than, or in addition to, growing them in a scattered manner of a few plants around the house; 2) an increase in the number of varieties of fruits and vegetables grown; and 3) an increase in the number of months of the year during which vegetables and fruits are grown. These changes in gardening practices markedly increase the amount and variety of fruits and vegetables produced. Households participating in the HKI Homestead Food Production program in Bangladesh currently produce an estimated 45,000 metric tons of vegetables and fruits (valued at US$7 million) on an annual basis, and the program provides employment to over 55,000 women in rural areas.

Homestead food production, as promoted by HKI's program in rural Bangladesh, is associated with a higher vitamin A intake.[5,8] More specifically, a higher vitamin A intake was associated with the type of garden, a larger total quantity of fruits and vegetables produced and/or a larger number of varieties of fruits and vegetables grown. Several other groups have also reported an increased production and consumption of vitamin A-rich foods after the start of homestead food production activities.[3,9-14]

One study suggests that gardening does not increase the demand for vegetables.[15] However, this study examined the impact of a commercial gardening program on vegetable consumption. These findings most likely reflect the different objectives of the program as well as the different economic status and motivations of participating households.

Nutrition surveillance data collected before and during a social marketing campaign promoting the consumption of dark-green leafy vegetables and eggs in Central Java, Indonesia, showed that the consumption of both types of food increased after the start of the campaign.[16] Also, an in-depth analysis of cross-sectional data collected by one round of the nutrition surveillance system in Central Java showed that the consumption of vitamin A from plant foods was higher in households with a homestead garden, whereas the consumption of vitamin A from animal foods was higher in households with a higher socioeconomic status.[17]

Potential direct and indirect ways for food-based programs to decrease miconutrient malnutrition

Food-based approaches can affect vitamin A status in various ways. The increased consumption of the vitamin A-rich foods, achieved either through promotion or production, can increase vitamin A status (direct impact); the production of foods in the homestead can increase income and enable the purchase of other foods rich in vitamin A, such as eggs, milk or liver (indirect impact); the consumption of vitamin A-rich foods could reduce morbidity and hence reduce the need for vitamin A (indirect impact); and increased empowerment of women could enable them to take better care of themselves and their children, and hence increase intake of vitamin A-rich foods and/or reduce morbidity (indirect impact).

Summary

Bioavailability of provitamin A and revised conversion factors

Until recently it was assumed that 6 µg of dietary β-carotene was equivalent to 1 µg retinol equivalents (RE).[18] A recent review of the original literature[19] and new research findings have challenged this assumption[20-24]. It now appears that the bioavailability of β-carotene and other provitamin A carotenoids from vegetables, but also from fruits, is much lower than assumed and varies widely.[19,25] β-carotene bioavailability depends on food preparation[26], especially fat content[27,28] and homogenization[29-31], and host characteristics, particularly parasitic infestation[32,33] and gastric acidity[34].

The significance of these recent findings about the lower bioavailability of dietary carotenoids has been acknowledged by two leading organizations in the field of nutrition in developed as well as developing countries. The U.S. Institute of Medicine (IOM) in 2000 recommended a conversion factor of 12:1 for calculating the 'retinol activity equivalents' derived from dietary b-carotene.[35] And the International Vitamin A Consultative Group has recognized that the bioavailability of dietary carotenoids varies widely and that the conventional conversion factor of 6:1 seems too optimistic.[36] Based on the IOM recommendation and the results of studies in Indonesia[21,37] and Vietnam[22], a conversion factor of 21:1 is recommended for dietary β-carotene, and 42:1 for other dietary provitamin A carotenoids[38,39].

Evaluating biological impact of food-based approaches

Based on these revised conversion factors, the expectation of an impact of food-based programs on VADD, particularly those based on an increased consumption of dark-green leafy vegetables, has become more modest. The strength of food-based approaches, however, is that they reach everyone throughout the life cycle, not just one particular group such as preschool children.[40] In addition, they can be adopted by households and communities in a self-sustainable way, and can have a positive impact on nutritional status, including VADD, in ways that go beyond improving vitamin A status through increased consumption of vitamin A-rich fruits and vegetables.[41] The consumption of fruits and vegetables has also been shown to play a role in preventing degenerative diseases[42] and mortality[43].

The real challenge of food-based approaches is in evaluating their impact on health and nutritional status.[41,44] The majority of the evaluations of food-based programs use the plausibility approach. This approach often uses experimental and quasi-experimental evaluation designs and cross-sectional surveillance data. It assesses dose-responsive relationships, changes in multiple indicators, and changes over time. This approach is the most appropriate way to assess the impact of food-based programs on nutritional and health status for several reasons.[45] First, study designs that involve the random allocation of subjects or households to treatment groups cannot be used. In addition, the identification of an appropriate control group is difficult. Finally, the impact of food-based programs may be modest and can be confounded by many factors, therefore larger-scale evaluations permit analyses that control for these confounding factors.

Sound decision-making for policies and programs will benefit from recognizing the different merits of controlled trials, intervention studies and evaluations of food-based programs, and most importantly their complementarity. In intervention studies, host-related factors that affect the impact of consumption of particular foods are usually controlled by involving only a particular target group and by intervening in order to have a relatively homogenous group of subjects, for example by deworming. Therefore, conclusions are limited to the particular group that was selected for the intervention and under the particular prevailing circumstances. In program evaluations, host-related factors are generally not controlled and when information is collected about them, they can be studied better and results of such evaluations can therefore differ from results of intervention studies[41] (for further elaboration, see Appendix 11, p110). When conducting a program, host-related factors can be taken into account by targeting specific target groups as well as by implementing particular interventions for optimizing carotene bioavailability, such as deworming.

Thus, while intervention studies can elucidate the relationship between 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. Therefore, the design of food-based programs can be based on intervention studies, but their impact has to be evaluated separately because of the many factors that play a role. Also, program evaluations can more easily reveal the impact of a particular intervention relative to that of another intervention, for example of food-based programs relative to that of vitamin A capsule distribution. Furthermore, while the impact of vitamin A capsules on health mainly varies with the host's need for vitamin A, the impact of food-based approaches can vary more widely, because it depends on the particular approach as well as on the environment under which the program is implemented.

HKI's experience in evaluating impact of food-based programs

HKI has evaluated the impact of food-based approaches in the Asia-Pacific region in several ways and found strong evidence that these approaches have a role in reducing VADD. A cross-sectional analysis of factors related to vitamin A status of women in Central Java showed that the intake of vitamin A from plant foods, ownership of a homestead garden, intake of vitamin A from animal foods, and socioeconomic status were all related to vitamin A status.[17,33] Using the plausibility approach, the impact of a social marketing campaign in Central Java that promoted consumption of dark-green leafy vegetables and eggs was evaluated by analyzing nutrition surveillance data collected before and during the campaign. Vitamin A intake, measured by several methods, increased as a result of the campaign. This increase in vitamin A intake was associated with an improvement in vitamin A status. The evaluation, which was carefully planned so that respondents were not aware of the link between the data collected and the campaign, concluded that the social marketing campaign improved vitamin A status.[16]

The impact of homestead food production in Bangladesh has been assessed several times since its inception. Firstly, in the early 1980s, it was found that children living in households with a homestead garden were less likely to be nightblind than children living in households without a homestead garden.[46] Secondly, baseline data collected at the start of the homestead food production program in the early 1990s showed that vitamin A intake was higher among households with a homestead garden[8], and that a higher vitamin A intake of women, which was nearly all from plant foods, was associated with less nightblindness and less diarrhea[47].

Thirdly, analysis of the data collected by Bangladesh's national vitamin A survey conducted in 1997-1998 among mothers and underfives in more than 24,000 rural households showed that among children aged 12-59 months who had not received a vitamin A capsule in the six months prior to the survey, the risk of nightblindness was lower when their house had a homestead garden.[48] Futhermore, the effect of vitamin A capsules on the risk of night blindness among children was less in households with a home garden than those without one. This suggests that home gardens provide additional protection against child night blindness. The analyses controlled for other factors, including morbidity and socioeconomic status. Furthermore, the survey showed that the risk of night blindness among women and children was significantly lower in households that had both home gardens and poultry, compared to households with either a garden or poultry or neither of these. Again, these analyses were controlled for socioeconomic status and morbidity. These findings provide important evidence of the more beneficial impact of homestead food production. Thus, for children in rural Bangladesh, both receiving a vitamin A capsule as well as homestead gardening contributed to reducing their risk of VADD. For other target groups, that are not eligible for receiving a vitamin A capsule, such as women, homestead food production is likely to be even more important for reducing the risk of VADD.

It is important to note that all the evaluations conducted in Bangladesh assessed the impact of homestead food production in general, and not specifically HKI's program. However, HKI's program successfully improves the production of the homestead gardens and increases the consumption of vitamin A-rich foods (see Appendix 2, p20, and Round Reports from Bangladesh and Cambodia, listed on p124), and therefore ensures that more and more households in the country experience the nutrition and health benefits of homestead food production. Other groups have also reported a reduction of VADD and/or related disorders, such as acute respiratory infections and reduced growth, after implementing homestead food production programs.[10,11,13,14,49]

While homestead food production has traditionally been practiced in rural areas, the HKI programs in the Asia-Pacific also extend to peri-urban and urban areas. The experience from the NGNESP in urban and peri-urban areas has shown that consumption of fruits and vegetables increased through establishing a homestead garden. Data from Indonesia collected before the onset of the economic crisis showed that vegetable and fruit consumption in urban areas was much lower than in rural areas, while consumption of fortified foods was much higher in urban areas.[50] However, in less affluent urban populations, in countries where only very few fortified foods are available, and/or in economically less favorable times, the consumption of fortified foods will be lower and dependence on other sources of micronutrient-rich foods, such as homestead food production, will be higher.

Additional impacts of homestead food production programs

When homestead food production programs and social marketing campaigns for the consumption of vitamin A-rich foods were first started, their main aim was to help combat VADD. Therefore, evaluations conducted by investigators in the nutrition field to assess the effectiveness of homestead food production programs have mainly focused on households' consumption of vitamin A-rich foods and, to a lesser extent, on nutritional status and health.[51] However, there are many more reasons why households and organizations conduct homestead food production. In combination with the recent findings that dark-green leafy vegetables and fruits contribute less to improving vitamin A status than previously assumed, the focus of homestead food production programs has gradually shifted.

First of all, the concept of homestead gardening has been broadened to also include the production of animal foods by having small animal husbandry, poultry and/or fish ponds. Animal foods have a higher content of micronutrients such as vitamin A, iron and zinc, and the bioavailability of these nutrients is generally much higher than the bioavailability from plant foods. Consumption of animal foods will therefore be an important contribution to combating micronutrient deficiencies. HKI is now planning to include the production of animal foods at the homestead and/or community level in its homestead food production programs in Bangladesh, Cambodia and Nepal.

Because the production of foods at the homestead is mainly the responsibility of women, they receive training and non-formal education as a result of the program, and become part of a social network through which they share experiences. This results in an increase of skills, confidence and self-esteem, and an increased role in household decision-making among women.[5] Also, it is very often the women who are responsible for the additional income earned from selling garden produce[3] and it has been found that, when this is the case, the money is largely spent on other good quality foods, education and health care (see Appendix 2, p20, and Round Reports from Bangladesh and Cambodia, listed on p124). This, in combination with the woman's increased self-esteem and decision-making capacity, contributes to improved health and nutrition of household members.

In addition to the role of homestead food production in women's empowerment, its role in income generation and poverty alleviation is also increasingly being recognized.[4] These outcomes may even become goals in themselves. Homestead food production is relatively independent of the macroeconomic environment and it largely benefits poor households and women in particular. Experience has shown that the work in the homestead is shared among household members and is therefore not a large burden on the women. In fact, many households are already growing some fruits or vegetables and are eager to increase their productivity when they have access to seeds, seedlings or saplings and can get technical support from the NGOs that participate in HKI's homestead food production programs. The eagerness of the households to participate is also illustrated by the fact that less than 3% of the households drop out of the program each year (data from Bangladesh and Cambodia).

Finally, the infrastructure that is created and/or strengthened by homestead food production programs can also be used to deliver other health or nutrition interventions, such as deworming or multi-micronutrient supplements for particularly vulnerable groups.

Conclusion

The above discussion presents clear evidence that homestead food production and social marketing campaigns for increased consumption of vitamin A-rich foods contribute to combating VADD. It is recognized that the amount of vitamin A obtained from the consumption of vitamin A-rich fruits and vegetables is on average 3-4 times lower than previously assumed and that there is therefore a need to complement it with consumption of animal foods as well as, for particular target groups, micronutrient supplements. Meanwhile, the scope of homestead food production is much wider than increasing vitamin A intake through consumption of self-produced vegetables and fruits. First of all, the production of animal foods is increasingly being incorporated into homestead food production activities. Secondly, an increased consumption of micronutrient-rich foods, an increase of income, and empowerment of women, all contribute to a better nutritional status, including vitamin A status, and health through improved diets and care-seeking. Thirdly, the role of homestead food production programs in income generation and poverty alleviation is increasingly being recognized.

HKI's work in this field demonstrates the importance of linking programs and research. In particular, the development and expansion of the NGNESP in Bangladesh characterizes the HKI/Asia-Pacific Regional Office's (HKI/APRO) approach of linking surveys and surveillance with programs and advocacy. It provides an example of a successful application of what the United Nations Children's Fund has termed the 'Triple-A Approach.' Between 1982 and 2001, HKI/APRO has used findings from surveys and surveillance, and recent scientific knowledge to design and develop programs. Experience gained from these programs are then taken back into routine surveys and surveillance to measure and explore the broader implications of the relationships between food, agriculture, health and nutrition (see Appendix 14, p119).

We strongly hope that this publication will further help to advocate for homestead food production programs and that these programs will receive the appropriate attention from governments and donors in the effort to combat malnutrition and poverty.

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Food-based strategies: Can they play a role in poverty alleviation?*

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Abstract

Over the past two decades the definition of poverty has been broadened to include social, economic, environmental and human development dimensions. In line with this shift of thinking, all countries committed at the G-8 Summit in Okinawa to achieve the International Development Goals to alleviate poverty by 2015. Development organizations, such as the international development banks, have committed to provide support to countries to reach the seven goals, including two goals that specify significant reductions of child and maternal mortality.

There is significant evidence that malnutrition, particularly micronutrient malnutrition, contributes to child mortality and growing evidence that malnutrition plays a similar role in maternal mortality. Inadequate dietary intake is an immediate cause of malnutrition and thus it seems logical that food and agriculture activities could contribute to improvements in nutrition and micronutrient status. Global availability of cereals is adequate, but the rate of undernourishment (inadequate caloric intake) is still high and child undernutrition still persists in many countries, suggesting that distribution of food is poor. Global availability of non cereal foods, such as animal and horticulture foods, is well below global requirements. Consequently, micronutrient deficiencies, which result mainly from inadequate intake of micronutrient-rich foods, particularly animal foods, are prevalent in most developing countries. Food-based strategies, such as home gardening, small animal husbandry, poultry, and social marketing, lead to better food production, food consumption and overall food security. Examining the relative contribution of the determinants of food security - availability, accessibility and consumption/choice - in a given setting provides insight into how the nutrition benefits from food-based strategies, as well as from macro food policies, might be maximized. When implemented in this context, food-based strategies can help countries achieve several of the IDGs.

Evolution of the definition of poverty and the international development agenda

Over the past two decades there has been a shift in thinking regarding the goals of international development. This change was stimulated in part by Sen, Dreze, Schultz and others, who introduced the concept that poverty goes beyond the traditional definition of lack of income to encompass economic, social and governance dimensions.[1,2,3] Sen further argues that poverty alleviation also requires better opportunities and freedoms for the poor.[4] This thinking was the basis for the development of the human development index (combining life expectancy, adult literacy and income to reflect health, education and resources, respectively), promoted by UNDP to rank a country's level of development. Although historically the programs and policies of the international development banks have emphasized economic growth, Sen and others influenced the strategic thinking and policies of these organizations at the international level as well as the process and content of their programs at country level. Motivated by the broader definition of poverty and re-focus in development, leaders of all

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countries agreed on International Development Goals (IDGs) to alleviate poverty by 2015 at the G-8 Summit in Okinawa. These goals combine economic growth, human development, environmental management and increased participation of women.[5,6] Measurement of poverty is beyond the scope of this paper, but it is an essential component of global as well as country-specific poverty alleviation strategies.[7,8]

Mortality reduction and nutrition

Two of the seven IDGs concern mortality – reduction in the mortality rates for infants and children less than five (5) years of age by two-thirds and reduction by three-fourths the maternal mortality ratio. A model showing the link between mortality, nutrition and food is presented in **Figure 1**. The majority of mortality in children is attributed to preventable diseases, such as acute respiratory infections, diarrhea, measles or malaria.[9,10] The main causes of maternal death are hemorrhage, eclampsia, and post-partum sepsis.[11] In this model, malnutrition, a main underlying cause of disease, is characterized by two arms - micronutrient malnutrition and energy or protein-energy malnutrition. The contribution of energy malnutrition, even moderate and mild malnutrition, to child mortality has been established,[12] although this contribution may not be equivalent for all diseases.[13] There is also evidence that micronutrient deficiencies are associated increased risk of child and maternal mortality. Improvements in vitamin A status result in a reduction of child mortality by at least 23% and, although more research is needed, results from a study in Nepal showed that vitamin A supplementation during pregnancy among deficient populations may reduce maternal mortality.[14,15] Other nutrients, such as iron, zinc, are essential for many

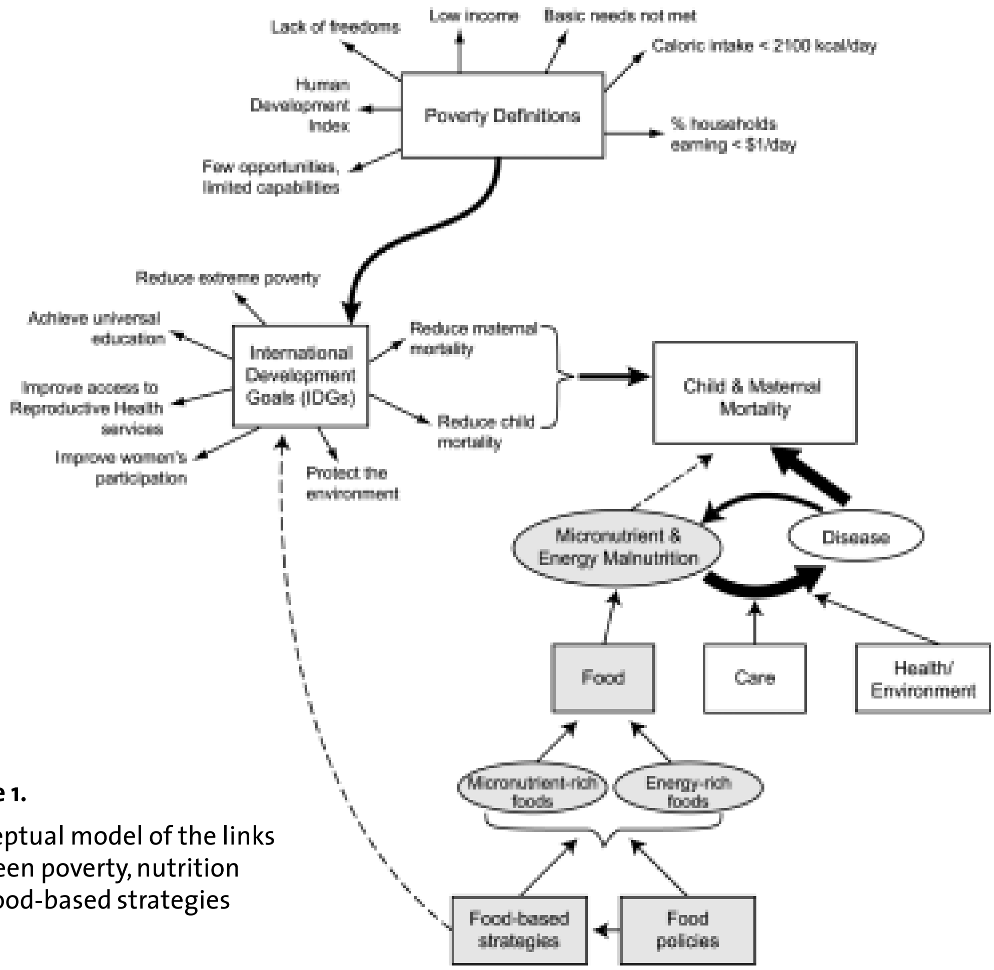


Figure 1.

Conceptual model of the links between poverty, nutrition and food-based strategies biological functions and for host immunity, thus deficiencies in these nutrients are likely to influence child and maternal mortality.[16,17,18] Although the two forms of malnutrition often co-exist and are inter-related in etiology, the quality of the diet (adequacy in terms of vitamins and minerals) is better reflected in micronutrient status, whereas changes in diet quantity are more likely to be reflected in anthropometry, particularly maternal BMI.[16,19,20]

Avenues to improve nutrition and micronutrient status

This new perspective, that improvement in nutrition and micronutrient status can help countries reach the IDG mortality goals, should be translated into policies and programs at the international, national, and community levels.[21] The multi-dimensional aspects of malnutrition, starting from its etiology, suggest that different sectoral approaches can be employed to improve micronutrient status. For instance, micronutrient status can be improved through supplements (iron tablets, vitamin A capsules). Incorporation of supplementation into health programs appears to be straight forward, but aside from the high-dose vitamin A capsule supplementation programs, which are administered bi-annually through campaigns, there has been limited success in effectively implementing programs for iron supplementation.[22] More is now being done to make these programs effective, but even so, supplementation alone cannot solve micronutrient deficiencies in many developing countries in the immediate future.

Food fortification can also increase micronutrient intake and has been successful in the developed world and particularly in several countries in Latin America.[23,24] However, despite the available technology, there are still several hurdles in the way of successful food fortification initiatives in many developing countries, including the challenge to manufacture fortified products that are within the economic reach of poor households. The role of social marketing programs is also important; their advantages and limitations are presented as part of food-based strategies below.

Inadequate dietary intake is an immediate cause of malnutrition and thus it seems logical that food and agriculture activities could also contribute to improvements in micronutrient status. The global availability of cereals has improved since the green revolution and is currently sufficient to meet global requirements. The rates of undernourishment, defined as inadequate caloric intake (calculated as only calories from cereals in some cases) have declined over the past 10 years, however, more than 790 million households still do not have enough to eat.[25] The prevalence of child undernutrition, measured most commonly as the percentage of children with weight-for-age below a reference standard, has also declined somewhat over the past decade.[26] However, the persisting high rates of both undernourishment and undernutrition suggest that the distribution of cereals and calories is inadequate.[27,28] Availability of most non cereal foods, including horticulture and animal foods, still falls short of global requirements and is certainly inadequate in many developing countries today.[28,29] With urbanization, economic development and rapidly changing dietary preferences, meeting non cereal food requirements in the future will be even more daunting.[29] Consequently, rates of micronutrient malnutrition, resulting from inadequate intake of micronutrient rich foods, particularly animal foods, are also extremely high in many countries.

At the country level, food includes both domestic production and economic (food) policies to support production and import. Successful economic growth will require the development of the rural economy; which will occur through a series of changes in most countries, including diversification of the agriculture production (to new products and beyond cereals) and development of the non-agriculture sector.[30] Because of the large gap between food availability, distribution and requirements and the serious negative consequences of malnutrition, all mechanisms for increasing food availability and food quality should be promoted. For countries that are transitioning from agrarian to a more diversified rural economy, food-based strategies, such as gardening, small animal husbandry programs, and poultry can contribute to food production and improve food availability and accessibility at the household and country level. Increased production of non-cereals in the farming system should also be promoted through food policies that support crop diversification and marketing. Inclusion of poor segments of the population into these schemes is essential if the goal is poverty alleviation.

Food-based strategies and food security

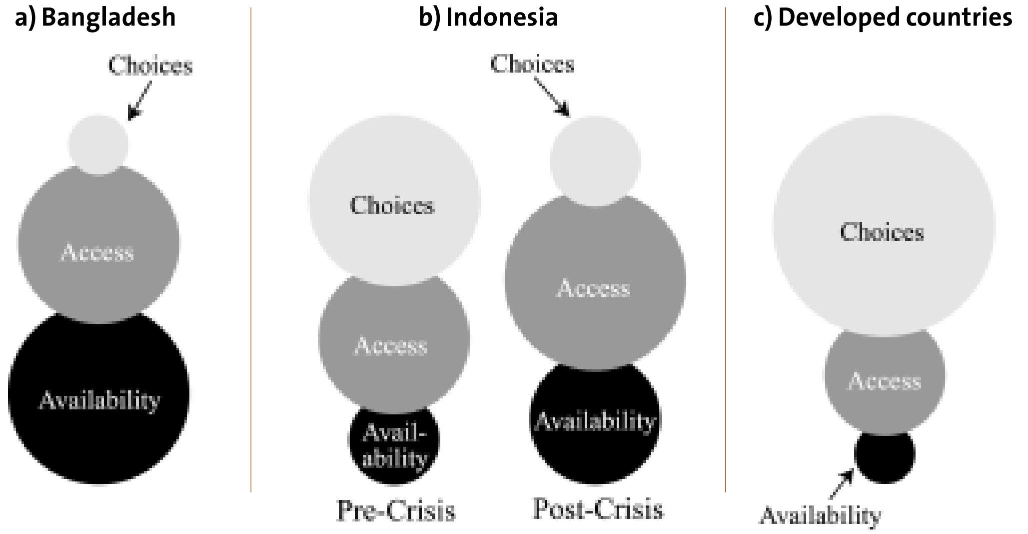
At the national, sub-national and household levels, food-based strategies should be examined in the context of food security. Traditionally, food security is categorized into three determinants: food availability, food access and food utilization.[31] Food availability refers to agriculture production, including cash crops, livestock and food crops. Domestic production may be enhanced by food imports. Food access refers to household purchasing power and the ability to secure foods from the market or other sources. Food utilization incorporates diverse aspects including sufficiency in required intake, food habits and preferences, intra-household distribution of food, food safety, and caring practices. We prefer to label food utilization as 'choice' because when accessibility and availability are ensured, utilization primarily represents household and individual 'choices' – for food, health care, and other opportunities.

While this three-tiered classification of food security is widely accepted, the relative contribution of these three determinants of food security varies across and within country settings, in response to crises or disasters, and over time. A good understanding of the balance between availability, accessibility and choice in a particular setting can be used to identify the most appropriate policies and programs to address food security. A comparison of several country situations will help to demonstrate the importance of this approach. Again, food security is defined as sufficient availability, access and 'choice' of cereals, legumes, animal and horticulture foods.

Figure 2a represents schematically the determinants of food insecurity among poor households in a country such as Bangladesh. In rural Bangladesh, adequate food availability is still a large problem. Although Bangladesh is nearly self-sufficient in cereal production, the availability of other foods, such as animal foods, dairy and fruits and vegetables is still well below the requirements.[32,33] In addition, more than 35% of the Bangladeshi population falls below the poverty line, thus food accessibility is also a major constraint to achieving food security.[34] In this situation, food choice is a much less important determinant of food security. Examination of food security in Bangladesh in this manner would suggest that social marketing or behavior change programs, should be coupled with programs to improve food availability and access, to improve food security. In fact, evidence from the HKI home gardening and nutrition education program in Bangladesh showed that production, coupled with information on complementary feeding and opportunities for women was associated with increased consumption/intake.[35,36]

In addition to variance across countries, crises and other events can change the determinants of food security. In **Figure 2b** we show a graphic comparison of the determinants of food security in Indonesia before and after the Asian economic crisis. Again, these figures are generalized, but suggest that prior to the crisis, availability and access were less important determinants of food security than in Bangladesh. In this setting, choice was a more important determinant. This scenario is supported by results from a social marketing program in Central Java that promoted increased consumption of eggs and vegetables. An evaluation of this program showed that egg consumption increased and micronutrient status improved after the campaign.[37] The economic crisis in Indonesia in mid-1997 increased food and other commodity prices and

Figure 2. Determinants of food security in Bangladesh, in Indonesia (prior to and after the start of the economic crisis), and in developed countries



reduced employment opportunities, thus lowering the real income and purchasing power of households. An examination of household egg consumption after the crisis revealed that weekly consumption declined.[19,38] When prices stabilized somewhat after the crisis and household purchasing power improved again, household expenditure of animal foods increased and childhood anemia rates decreased. This scenario suggests that during this crisis period, social marketing alone would probably have been ineffective in increasing the consumption of eggs or other high quality foods such as animal foods or fortified foods. This example in Indonesia shows how an understanding of the relative contribution of the determinants of food security can influence the type of programs that may be most effective.

Figure 2c portrays the relative determinants of food security in developed countries. In this scenario, the main determinant is choice, which coincides with the major role of the food industry, food packaging and consumer food marketing that exists in many of the developed countries.

Food-based strategies and micronutrient status

There is growing evidence that food-based strategies, including home gardening have an impact on vitamin A deficiency and other micronutrient deficiencies. In Bangladesh, a comparison of two surveys suggested that a decline in the prevalence of night blindness occurred both among vitamin A capsule (VAC) recipients and non-recipients over the 15-year period. A decline of night blindness among the group who did not receive the VAC suggests that underlying causes, including vitamin A intake, had improved. These studies both showed that the current risk of night blindness was lower among children in households with homestead gardens.[39,40] Controlling for socioeconomic status, the prevalence of night blindness was 3.6% among mothers in households without gardens compared to 3.1% and 2.7% among households with either garden or poultry, compared to 1.9% among women in households with both poultry and gardening (c^2 test for trend, $p<0.01$). Home gardening was associated with a higher intake of vegetables and lower risk of vitamin A deficiency among women in Central Java, Indonesia.[41] A study in Ethiopia showed that home gardening, linked with a dairy goat project, increased the intake of vitamin A rich foods. Women/children in households who participated in home gardening had lower prevalence of night blindness than the control group.[42] Also, as described above, a social marketing campaign in Central Java led to an increase in egg and vegetable consumption and improvements in vitamin A status. These findings suggest that there is a role for food based strategies in improving micronutrient status.

Food policy and micronutrient deficiency

The links between nutrition and macro food policy and economic development have been introduced previously.[43,44] However, although improved economic development is associated with a reduction of mortality, morbidity and malnutrition, there is limited data that allows a thorough examination of the impact of macro food policies, such as food prices, on nutritional status.

Recent analyses from the Nutrition Surveillance Project in Bangladesh showed that the decline in rice prices was strongly correlated with a decline in child nutritional status. Rice consumption did not change during this time period, but the decline in rice price was associated with an increase in household expenditure on non cereal foods. The increase in expenditure on non cereal foods was also strongly correlated with the decline in child malnutrition (underweight), suggesting that an increased intake of micronutrient-rich foods contributed to this decline.[45]

The economic crisis in Asia has provided a unique opportunity to examine nutrition and food policy. Analysis of data from Indonesia suggests that the Asian economic crisis increased the prevalence of iron and other micronutrient deficiencies and maternal wasting.[19,20,38] Data from the NSS supports the hypotheses that the events of the crisis would have a larger impact on household access to more expensive food items (e.g., animal foods and fortified foods), thus reducing consumption of micronutrient-rich foods. The decrease in intake of quality foods led to an increase in the prevalence of micronutrient deficiencies and ultimately to a 'lost generation' and increased mortality. Since 1999, the economic situation in Indonesia has improved slightly and the NSS shows an increase in the share of household food expenditure on animal foods and an improvement in the prevalence of anemia among children 12-23 months of age in urban poor areas in Jakarta declined. Food policy responses to these types of crises can influence access to micronutrient-rich foods and therefore can positively or negatively affect nutritional status.

Conclusions

The broader definition of poverty and the accompanying shift in development goals makes the role of nutrition in poverty reduction and international development more evident. The links between nutrition and mortality, observed more than a century ago, are being substantiated with new research. At the same time, the source of nutrients and energy – food – is also being examined with greater intent for the World Food Summit. Global food availability, including the availability of animal foods, and food security are major components of poverty alleviation. The role of agriculture and the importance of the development of the rural economy, (despite or perhaps more importantly because of urbanization trends) make this discussion of food-based strategies in the context of food production, food security and poverty alleviation equally noteworthy. Although not within the scope of this paper, the benefits of food-based strategies towards alleviating poverty go beyond their impact on micronutrient status and maternal and child mortality. Food-based strategies can improve household income, increase women's involvement in decision-making, and enhance the skills of women and other household members, benefits that are part of the other seven IDGs. Furthermore, there is significant evidence that micronutrient malnutrition has functional consequences, such as slowed cognitive development and physical growth in children and lower work productivity.[46] Thus prevention and control of micronutrient deficiencies also contributes to future development by expanding the capabilities of the poor and enabling them to use education and technologies more effectively. Finally, we cannot ignore the debate about measurement of poverty. The inclusion of indicators of dietary quality, such as the starchy-staple ratio, or micronutrient status, such as childhood anemia, may be useful for the monitoring progress towards reaching the broader goal of poverty alleviation.

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Appendix 2

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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

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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 garden-

Appendix 2

ing. 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

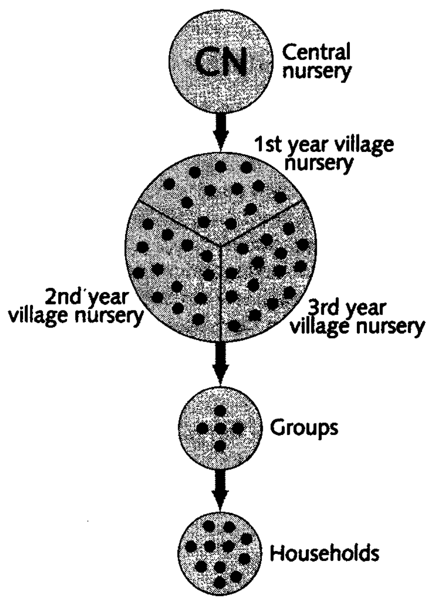

FIG. 1. Model for implementation of Bangladesh homestead gardening programme at the subdistrict level. In this model, each subdistrict has 1 central nursery, 45 village nurseries, and 4,500 households

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% ($p < .001$, χ^2 test). In addition, the percentage of households without a home garden decreased from 25% at baseline to less than 2% after one year ($p < .01$, χ^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.

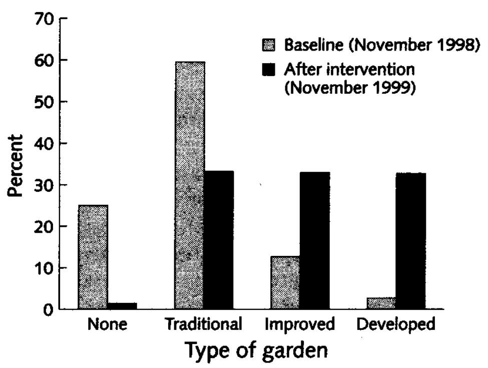

FIG. 2. Changes in gardening practices after one year of programme participation ($n = 622$)

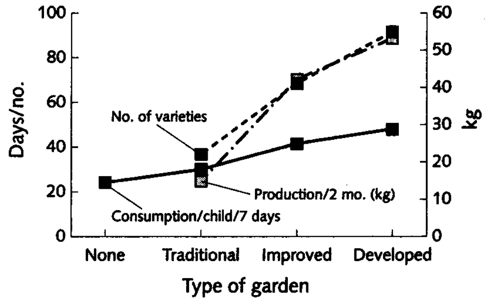

FIG. 3. Vegetable production and consumption according to type of garden ($n = 10,107$)

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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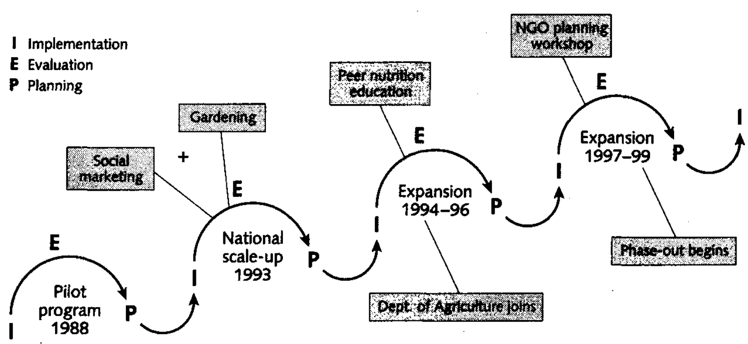

FIG. 4. Evolution of the Bangladesh homestead gardening programme

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.

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Appendix 3

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Production of fruits and vegetables at the homestead is an important source of vitamin A among women in rural Bangladesh

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Background: Vitamin A deficiency is considered to be an important public health problem in Bangladesh. A universal biannual distribution of high-dose vitamin A capsules has been in place for over the past two decades. This supplementation has been beneficial for preschool children. Bangladesh has been exploring more sustainable approaches for all segments of the population. To support this initiative, Helen Keller International has implemented a home-gardening promotion project since 1993. This project is executed on a large scale and currently reaches an estimated 244 000 families.
Methods: This paper presents data from 7341 women of reproductive age which were collected as part of the baseline census of a community monitoring system whose objective is to track progress and measure the impact of home-gardening activities.
Results: Vitamin A intake in this population derived almost entirely from the consumption of fruits and vegetables. Logistic regression analyses showed that maternal vitamin A intake was determined by qualitative indicators of homestead gardens (type of home garden, the total quantity of provitamin A-rich foods produced and the number of fruits and vegetables varieties grown in the garden) after adjusting for socio-economic status.
Conclusions: These results indicate that traditional production of provitamin A-rich fruits and vegetables in the homestead may provide a valuable contribution to vitamin A intake in communities where alternative dietary sources of vitamin A are scarce.
Descriptors: home-gardening, Bangladesh, provitamin A, fruits, vegetables

Introduction

Vitamin A deficiency is one of the world's most serious public health problems. This deficiency has always been known to be the main cause of preventable childhood blindness. Several reports over the past decade have shown that vitamin deficiency is also associated with increased mortality and an increased severity of infectious diseases (Beaton *et al* 1993). Xerophthalmia has been identified as a major public health problem in Bangladesh since the early 1970s. The extent of the problem in Bangladesh was further documented in a National Nutritional Blindness Study in 1982–1983 (Cohen *et al*, 1985). The study estimated that each year 30 000 or more children become blind and that over a million Bangladeshi children under 60 months of age suffer from some form of eye disease due to vitamin A deficiency.

Several strategies have been developed to detect and prevent vitamin A deficiency. The biannual distribution of high-dose vitamin A capsules to children under 60 months of age has been an early and valuable response to this problem in Bangladesh. A recent evaluation of this programme showed that vitamin A supplementation is an effective strategy for reducing vitamin A deficiency (Bloem *et al*, 1995). Because this programme is beneficial for preschool children, Bangladesh has been seeking more sustainable approaches for the entire population, since several recent reports from three countries in Southeast Asia have shown that vitamin A deficiency is also prevalent among women of reproductive age (Bloem, Huq & Matzger, 1994; Bloem & Gorstein, 1995; Katz *et al*, 1995).

Home-gardening is a traditional family food production system widely practised in Bangladesh and is mainly used to increase the availability of food for consumption at the household level. The production is, however, mainly seasonal and there are several agricultural constraints which are difficult to overcome for the poor. Since 1988, Helen Keller International has been implementing community home-gardening promotion projects, which aim at improving the quality and to expand the home-gardening approach in Bangladesh. Nonetheless, there is still some questioning as to whether home-gardening leads to a higher intake of provitamin A or whether the fruits and vegetables produced are mainly sold to generate income for the household.

This paper presents data collected as part of the baseline survey of a community-based monitoring system in areas where the home-gardening programme is being implemented. The paper examines the contribution made by the production of fruits and vegetables in traditional home-gardens to the vitamin A provision of women of reproductive age.

Methods

This paper presents analyses of baseline data collected from the Helen Keller International home-gardening monitoring system from November 1993 to March 1994. The design of the monitoring system includes ongoing measurement of a longitudinal cohort in which children and their mothers are followed up over a 3-y period. The project is being conducted in 360 villages located in ten districts in several regions of Bangladesh.

Sampling
A three-stage sampling design was used to select households for the ongoing monitoring system. First, ten districts were selected by simple random sample (SRS) from the total number of 30 in the project area. In the second stage, population data from a 1985 census provided by the Bangladesh Bureau of Statistics were used to select 36 villages from each district employing a population proportional to size (PPS) sample procedure. Subsequently, within each selected village, a random selection was made of a single target household from all eligible households. A systematic procedure was then used to select other households until a minimum of 30 children per village were selected. Within each selected household, one mother of reproductive age and all of her children under 60 months of age (average number of children per mother was 1.5) were enrolled. A total of 7341 mothers were included in the sample en were the focus of the analysis described in this paper.

Data collection
By interviewing the selected mother, another parent, guardian or responsible adult in the household, data were collected on family size, number of children under the age of 60 months, education level of the mother, area of agricultural land and homestead garden owned, type and size of garden, and size of the house. Two categories of agricultural land were considered: less than $2000\,m^2$ and more than $2000\,m^2$. Agricultural land is mainly used for rice and other cash crops and is used in our study as a proxy indicator of economic status of households. The homestead gardens are used for the production of fruits and vegetables. The three types of homestead garden recognized were: a fixed garden (i.e. a single area cultivated by the family), a scattered garden (comprising several relatively small areas of cultivated land) and a mixed garden (a combination of fixed and scattered gardens).

Dietary intake
A modification of the International Vitamin A Consultative Group guidelines (IVACG; 1989) was implemented to measure the approximate intake of vitamin A in the survey population. The IVACG guidelines have been developed to enable estimation of both current intake (by estimating food consumption in the previous 24 h) and the usual pattern of consumption over longer periods of time to correct for daily and seasonal variations in the variability and intake of provitamin A-containing foods.

During data collection, each mother included in the sample was asked about the consumption of foods in the previous 24 h grouped into five distinct categories based on their vitamin A content. Bangladeshi food composition data was used to establish the five food groupings (Darnton-Hill *et al*, 1988). Three of the categories used were for vegetable sources of provitamin A carotenoids, including those with a high vitamin A content (>250 retinol equivalents (RE) in a small serving size), moderate vitamin A content (50–250 RE) and low vitamin A (<50 RE). The other two categories detail animal foods with moderate to high vitamin A content (>250 RE), and those low in vitamin A (<250 RE). It should be noted that although animal foods are included in the IVACG methodology, they are combined with fruits and vegetables into one of three other categories. In the present work, animal foods have been included in separate categories since it is of interest to identify the sources of vitamin A being consumed. The relative contribution of fruits and vegetables as provitamin A sources to total vitamin A intake is important, as these are the foods being promoted by the project. Dietary intake data are used to estimate vitamin A intake, and are expressed both as totals and by source, i.e. animal products or fruits and vegetables.

Calculations of the daily intake pattern required information about the frequency of consumption of three standardized portion sizes in the previous 24 h for foods in each of the five groups. It is important to emphasize that with this method, information was sought on the consumption of foods in the previous 24 h rather than on the previous day. For each food group, the consumption was calculated from frequency × portion size. As the relative sizes of the three standardized portions are 1 : 2 : 4, it is possible to calculate the total frequency for an average portion size. Data colected in the field were presented in terms of the largest portion consumed, and the appropiate frequency was calculated.

From the data collected on the frequency and average portion size of foods in the five groups, the vitamin A intake levels were estimated. Based on these values, mothers were grouped into percentiles which grouping is intended to serve as a qualitative measure of relative intake. The methodology does not allow for a determination of the actual vitamin A intake level, and it is important that the limitations of the method are recognized.

Statistical analysis
Data analysis was carried out with the statistical package SPSS for Windows, version 6.1 (Norusis, 1993). Comparisons between mean values were made by Student's *t*-test and ANOVA, while analysis which compared differences between proportions were assessed by χ^2 test statistics. Multivariate analyses were undertaken by using logistic regression methods to test models which could best characterize the factors influencing vitamin A intake among mothers. Logistic regression coefficients are presented as antilogarithms (thus, as odds ratios).

Results

The vitamin A intake of the women in the study is presented in Table 1. Mean daily intake of vitamin A from all sources was 511 RE, and median intake was 400 RE (falling within the range of 49.1–60.4% of the cumulative percentage). Median intake of vitamin A from fruits and vegetables was 300 RE (49.5–54.8% of the cumulative percentage), while 80.7% of the population did not consume any animal source of vitamin A.

Table 2 presents the characteristics of the women whose vitamin A intake from all sources was either above or below the median value. Vitamin A intake was found te be significantly associated with family size, area of arable land, number of varieties of fruits and vegetables cultivated in the garden at the time of data collection, house size, maternal education and type of garden.

Table 3 presents the characteristics of households by type of the gardening method. Both the size of arable

Table 1 Daily vitamin A intake by women of reproductive age in rural Bangladesh, November 1993–March 1994

		Vitamin A intake (RE/day)[a]				
Vitamin A source	*n*	*mean*	*s.d.*	*P25*	*P50*	*P75*
Animal sources	7341	67	20	0	0	0
Fruits and vegetables	7318	444	556	100	300	600
All sources	7318	511	575	100	400	600

[a] RE, retinol equivalents.

Table 2 Characteristics of women of reproductive age whose total vitamin A intake per day was above or below the median (400 RE/day) in rural Bangladesh, November 1993–March 1994

	Vitamin A intake					
	Below median			*Above median*		
	Mean	*SD*	*n*	*Mean*	*SD*	*n*
Family size	5.7	2.1	3574	5.9[a]	2.3	3717
Number of children < 60 months	1.63	0.76	3588	1.62	0.73	3724
Arable land (m^2)	72	48	3589	99[a]	49	3724
Homestead garden (m^2)	210	4.7	3586	220	2.5	3723
Number of varieties per garden	2.6	1.58	3085	3.0[a]	1.62	2758
House size (m^2)	15.0	1.55	4007	15.8[a]	1.52	3727

	n	*Proportion of mothers with vitamin A intake above median*	*Odds ratio (95% CI)*	*P*
Maternal education				
None	4713	51.3	1.00	
≥1 year	1550	54.4	1.13 (1.01–1.27)	0.0327
Arable land				
≤2000 m^2	5102	49.4	1.00	
>2000 m^2	2210	54.4	1.22 (1.10–1.35)	0.0009
Type of homestead garden (for cultivation of fruits and vegetables)				
Fixed	585	39.1	1.00	
Scattered	3740	53.7	1.80 (1.51–2.15)	0.0000
Mixed	1534	56.7	2.05 (1.69–2.49)	0.0000

[a] $P < 0.001$: in statistics (Student's *t*-test), continuous variables (upper half of the table) were transformed by natural logarithm; means and s.d.s are presented in the table on original scale. χ^2 analysis for categorical variables (lower half of the table).

Table 3 Characteristics of households by type of the homegarden in rural Bangladesh, November 1993–March 1994 ($n = 5906$)

	Garden type					
	Fixed		*Scattered*		*Mixed*	
Variable	*Mean*	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Arable land (m^2)[a]	113	44.7	67	44.7	610	30.0
Homestead land (m^2)[a]	225	3.4	222	4.9	386	3.4
Number of varieties per garden[a]	2.1	1.55	2.4	1.51	4.7	1.45
House size (m^2)[a]	15.3	1.58	15.7	1.54	16.4	1.51

[a] $P < 0.001$: in statistics (ANOVA), continuous variables were transformed by natural logarithm; means (not s.d.s) are presented in the table on the original scale.

land owned and the number of varieties of fruits and vegetables produced in the garden differed significantly between households with fixed gardens and those with scattered gardens. The scattered gardening approach is practised by households with less arable land. However, by using more small spots, these households had produced more varieties of fruits and vegetables in their garden than households with fixed gardens. The households with mixed gardens, i.e. those combining fixed and scattered gardens, had significantly more arable land, a larger homestead garden, more varieties of fruits and vegetables per garden, and a larger house than households practising either of the two gardening methods alone.

Table 4 shows the results of three logistic regression models which were tested to evaluate the odds associated with an adequate vitamin A intake above the median. The first model showed that the determinants of total vitamin A intake included type of garden and number of varieties and amount of fruits and vegetables produced per garden.

By including vitamin A intake from fruits and vegetables in the second model, five variables were found to be associated with vitamin A intake (from all sources): type of garden (scattered gardens, mixed gardens), house size, maternal education, number of children under 60 months of age, and vitamin A intake from fruits and vegetables. This model clearly demonstrated that vitamin A intake from fruits and vegetables is the most important factor in capturing the variability of vitamin A intake in this population. The other variables (type of garden, house size, maternal education, number of children under 60 months of age) in model 2 are the determinants for vitamin A intake from animal sources and reflect that vitamin A intake from animal sources is associated with a higher socio-economic status of the households.

The third model was similar to the second one except that instead of adding vitamin A intake from fruits and vegetables, a variable was included on maternal vitamin A intake from animal sources. This final model shows that vitamin A intake from animal sources contributed

Table 4 Logistic regression analyses of the odds of having a vitamin A intake above the median (>400 RE per day from all sources) among women of reproductive age in rural Bangladesh, November 1993–March 1994 ($n = 4969$)

Variable	*Odds ratio*	*(95% CI)*	*P*
Model 1			
Type of garden			
Fixed	1.00		
Scattered	1.95	(1.60–2.38)	0.0000
Mixed	1.56	(1.24–1.96)	0.0001
Number of varieties per garden	1.54	(1.34–1.78)	0.0000
Total fruits and vegetables produced (kg)			
below median	1.00		
above median	1.39	(1.23–1.57)	0.0000
Model 2			
Type of garden			
Fixed	1.00		
Scattered	1.85	(1.26–2.70)	0.0016
Mixed	1.68	(1.12–2.54)	0.0132
House size (m^2)	1.95	(1.52–2.49)	0.0000
Maternal education			
None	1.00		
⩾1 year	1.39	(1.10–1.76)	0.0052
Number of children under 60 months of age in the households	0.86	(0.75–0.99)	0.0475
Vitamin A intake from fruits and vegetables			
⩽median (⩽300 RE/day)	1.00		
>median (>300 RE/day)	293	(219–393)	0.0000
Model 3			
Type of garden			
Fixed	1.00		
Scattered	2.08	(1.69–2.54)	0.0000
Mixed	1.67	(1.33–2.11)	0.0000
Number of varieties per garden	1.56	(1.35–1.80)	0.0000
Maternal education			
None	1.00		
⩾1 year	0.87	(0.77–0.98)	0.0453
Vitamin A intake from animal sources			
⩽100 RE/day	1.00		
>100 RE/day	2.40	(2.06–2.80)	0.0000
Total fruits and vegetables produced (kg)			
below median	1.00		
above median	1.38	(1.22–1.56)	0.0000

Type of garden, number of varieties of fruits and vegetables in the garden, maternal education and number of children under 60 months of age were treated as discrete variables. All other data were treated as continuous variables: data on size of homestead was transformed to the natural logarithm prior to analysis. In the analysis, correction was made for the following variables:
Model 1: area of arable land and homestead garden, house size, maternal education, size of family, and number of children under 60 months of age;
Model 2: area of arable land and homestead garden, number of varieties of fruits and vegetables per garden, vitamin A intake from animal sources, and size of family and
Model 3: area of arable land and homestead garden, house size, vitamin A intake from fruits and vegetables, maternal education, size of family, and number of children under 60 months of age.

to total vitamin A intake (OR = 2.40; 95% CI = 2.06–2.81) but not to the same extent as vitamin A intake from fruits and vegetables contributed to total vitamin A intake in model 2 (OR = 293; 95% CI = 219–393). The indicators of homestead gardens, i.e. type of garden, amount of fruits and vegetables produced and number of varieties of fruits and vegetables per garden were significant in the third model and had similar coefficients as in model 1. However, in model 3, maternal education was inversely associated with vitamin A intake. This model reflects the determinants of vitamin A intake from fruits and vegetables and shows that women from poorer households with less education are more dependent on these provitamin A sources than women with more education. Higher education was found to be positively associated with an increased intake of vitamin A from animal sources.

An interesting observation is that type of the garden and number of varieties produced remained relevant in all three regression models, and are therefore associated with both vitamin A intake from fruit and vegetables sources and vitamin A intake from animal sources. The odds ratios, however, in the third model showed that these indicators are more associated with vitamin A intake from fruits and vegetables. Although scattered gardens were associated with households with a lower socio-economic status than mixed gardens (Table 3), the odds of having a vitamin A intake above the median were highest for women of households with scattered gardens in all three models. Fruit and vegetables produced in scattered gardens are therefore more likely to be used for consumption than fruit and vegetables produced in households with mixed gardens.

Discussion

Vitamin A deficiency is still a public health problem in Bangladesh (Bloem *et al*, 1994). Several strategies have been developed to tackle this micronutrient deficiency at a global level. One of the short-term measures widely implemented has been the distribution of high-potency vitamin A capsules. This strategy was adopted two decades ago by Bangladesh and has been found to be an effective strategy to reduce xerophthalmia and vitamin A deficiency among preschool children (Bloem *et al*, 1995). Other strategies such as food fortification and home-gardening have not received similar attention. However, several non-governmental organizations have carried out pilot projects in Bangladesh (Pollard & van der Pash, 1990; Ali, Bloem & Pollard, 1993; Marsh *et al*, 1995). The data presented in this paper are from Helen Keller International's large home-gardening programme funded by the US Agency for International Development since 1993 (Talukder *et al*, 1993).

One of the pilot projects showed some promising results because the project based its strategy on improving the traditional cultivation of fruits and vegetables instead of imposing new methodologies. The other key factor which may have contributed to its success included its focus on women as mothers, gardeners, group leaders, and decision makers within the household, and its promotion of low-input, low-cost gardening techniques, including seed production (Marsh *et al*, 1995).

An important observation emerging from the preliminary logistic regression analysis was that the number of varieties produced in the home-garden was significantly associated with a higher vitamin A intake. Initially, we believed that this may have been due to an increased production of fruits and vegetables in the garden. However, subsequent analysis (Table 4) showed that even after controlling for the quantity of fruits and vegetables produced, an increase in number of varieties grown in home-gardens independently and significantly improved the odds of a mother having an adequate vitamin A intake. This seems to imply that the diversity of the diet was better among households producing the widest variety of fruits and vegetables, and this enhanced total vitamin A intake.

A home-garden is an area around the home where different fruits and vegetables may be grown throughout the year to meet family nutritional requirements. There are three main types of home-gardens practised in Bangladesh: fixed, scattered and mixed gardens. In a fixed garden, the land is compact and can be divided into different sections and planting beds as necessary; a scattered garden consists of plots on several different locations; and a mixed garden is a combination of both practices. In Bangladesh, the fixed garden is traditionally associated with cash cropping and the production of fruits and vegetables for commercial purposes instead of for consumption. It is clear from Table 3 that households with mixed gardens have more homestead and arable land, and are therefore economically better off than households with either scattered or fixed gardens. As would be expected, the production of fruits and vegetables is also higher in these households.

A second interesting observation arising from the analysis was that the vitamin A intake of mothers was highest in households with scattered gardens, in spite of the fact that these households were economically the least well off. Furthermore, vitamin A intake from animal sources was also higher in those households with scattered gardens than in households using the other garden approaches. Taking into account the fact that scattered gardens are adopted by poorer households, these observations may reflect their tendency to utilize the limited resources available in the most efficient way possible, while households with mixed or fixed gardens may tend to produce provitamin A-rich foods for commercial purposes. Finally, it was important to observe that model 2 of the logistic regression, which reflected the intake of vitamin A from animal dietary sources, was mainly determined by indicators of socio-economic status.

This study shows that vitamin A intake among women of reproductive age in Bangladesh is mainly determined by the availability of vegetables/fruits at a household level. Understanding of and adaptation to local conditions are essential elements in successful home-gardening projects (Brownrigg, 1985). The fact that these data are based on the contribution of traditional available home-gardens to the provitamin A intake of women in rural Bangladesh shows the enormous potential of home-gardening projects in Bangladesh. However, the next question is whether a higher vitamin A intake through increase of β-carotene-rich foods had beneficial effects on maternal health.

Appendix 3

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Social marketing
Vitamin A intake
Eggs
Dark-green leafy vegetables
Vitamin A status
Indonesia

Impact of a Social Marketing Campaign Promoting Dark-green Leafy Vegetables and Eggs in Central Java, Indonesia

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Summary: In order to work towards further reduction of vitamin A deficiency in central Java, Indonesia, a social marketing campaign promoting eggs and dark-green leafy vegetables was initiated in March 1996. The nutritional surveillance system (December 1995–December 1996) found the following. The campaign's messages were well noticed. Consumption of at least one egg in the past week increased from 80% to 92% in mothers and from 78% to 92% in children 12–36 months old. It increased in all socio-economic groups and was independent of ownership of chickens. Most eggs had been purchased. The quantity of vegetables prepared increased from 93 to 111 g/person daily and most was purchased. Vitamin A intake increased from 335 to 371 RE/d for mothers and from 130 to 160 RE/d for children. Serum retinol levels increased after the start of the campaign, and were related to egg consumption and vitamin A intake. Because 1. data were collected in such a way that respondents were not aware of the link between data collected and the campaign, and 2. vitamin A status increased and was related to increased consumption of eggs and vitamin A intake, we conclude that the social marketing campaign was successful.

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Introduction

Several strategies are being used to work towards reaching the goal of virtual elimination of vitamin A deficiency by the year 2000 set at the World Summit for Children in 1990. This includes the distribution of high-dose vitamin A capsules to groups at risk such as children under 5 years of age and women within a few weeks after delivery, and increasing the availability and consumption of foods naturally rich in vitamin A[1] or fortified with vitamin A.

Indonesia has a long history of combating vitamin A deficiency. Since the early 1970s, high-dose vitamin A capsules have been distributed to children aged 12–59 months, and since 1991 women have been given a high-dose vitamin A capsule within one month after delivery. In addition, the promotion of vitamin A-rich foods has been an essential component of nutrition education [1]. From the mid 1980s, social marketing has been used for promoting both the distri-

[1] It has been agreed internationally that vitamin A intake is expressed in retinol equivalents (RE) and that it is calculated by adding up the vitamin A originating from animal foods, counting 1 μg retinol as 1 RE, and the vitamin A originating from plant foods, counting 6 μg of β-carotene or 12 μg of other provitamin A carotenoids as 1 RE.

bution of high-dose vitamin A capsules and the consumption of vitamin A-rich foods.

While the promotion of vitamin A-rich foods has emphasized plant foods, a social marketing project in Central Java in 1991–1994 promoted the consumption of eggs. The sole promotion of an animal source of vitamin A was a novel idea. The reasons for this choice were that eggs are a good source of vitamin A, that their availability, acceptance and affordability were reasonable, and that they can be prepared in many different ways. In 1996, UNICEF Indonesia initiated a project in central Java to improve survival of children under 2. One of the strategies used was to increase vitamin A intake by children and their mothers. On the basis of the findings of formative research it was decided to promote eggs as well as dark-green leafy vegetables. The main message spread by the campaign was "One egg and a bowl of vegetables are healthy foods for every day: they will make underfives healthy and clever and stimulate breast milk production".

In order to monitor the impact of the campaign, a nutritional surveillance system was set up. Information was collected to enable changes in knowledge, attitude and practice as well as their impact on vitamin A status and morbidity to be monitored. Until now, only one other social marketing campaign on vitamin A which also evaluated its impact on vitamin A status has been reported [2]. That campaign clearly increased the consumption of ivy gourd in northern Thailand, but its impact on vitamin A status was inconclusive [2].

The social marketing campaign in Central Java started in March 1996 and covered the entire province with a population of more than 30 million people. Data were collected every three months, from December 1995 to December 1996.

Subjects and methods

Subjects and sampling design: In total, five waves (rounds) of data collection were conducted by the nutritional surveillance system (December 1995–January 1996, March–April 1996, June–July 1996, September–October 1996, and December 1996–January 1997). Each wave lasted six weeks and for each wave a new random sample of 7200 households was selected, using a multi-stage cluster sampling design. Central Java consists of six ecological zones. From each zone, 30 villages were selected by probability-proportional-to-size sampling. Each village provided a list of households with a child ≤ 36 months old. From this list, 40 households were selected by interval sampling, using a random start.

A subsample of all households from six randomly selected villages per zone was selected for blood collection from the mother and her youngest child for measuring blood haemoglobin and serum retinol. For waves 1 and 3, 1100 households with youngest child ≤ 24 months old were selected. For waves 4 and 5, 1440 household with a child < 5 months of age were selected. Written informed consent was obtained before blood collection. This procedure had been approved by the Medical Ethical Committee of the Indonesian Ministry of Health.

Data collection: coverage and quality control: Data were collected from almost all (98–100%) of the households selecetd for each wave. For waves 1, 3, 4 and 5, blood was collected from 35, 57, 73 and 75%, respectively, of the mothers in the selected households and from 31, 39, 70 and 72%, respectively, of the target children in the selected households. The increase in the proportion of subjects from whom blood was collected coverage was attributable largely to the increasing ability of the blood collection team to gain the confidence of and cooperation from the community.

Data were collected by a total of 40 enumerators who were graduates from Indonesian schools of dietetics. Each team of four was supervised by one field supervisor. For quality control, each team revisited 10% of the households visited by another team. After data entry, the performance of each enumerator was evaluated by comparing the data with the quality control data. This was discussed in the refresher training organized before each new wave of data collection, in order to optimize the enumerators' performance.

Methods for data collection

General questionnaire: The general questionnaire collected information on household composition, educational background of husband and wife, occupation of the main earner, sanitary conditions, land owned, food produced, livestock owned, knowledge of vitamin A and the source of such knowledge, source of eggs, source and consumption of vegetables, and use of oil and coconuts. In addition, anthropometric measurements were taken and data on vitamin A intake, receipt of a vitamin A capsule, egg consumption and morbidity were collected from the woman and her youngest child.

Source of information about vitamin A: Respondents were asked whether they had heard about vitamin A and, if so, by which means or from whom. The latter was an open question, the answers to which were coded into pre-set categories.

Egg and vegetable consumption: The following question was asked about egg consumption: "When did you last consume an egg: within the past 24 h, 1–3 days ago, 4–7 days ago, over a week ago, or never?". Questions about vegetable consumption were as follows: "Did you prepare any vegetables in the past three days? If yes, indicate how much (kg) was prepared from each source (purchase, garden, gift, exchange, gathering, other)." From this answer, the amount prepared per household member per day in the previous three days was calculated, with children < 6 years old regarded as counting 50% of that of adults.

Vitamin A intake: A 24-h recall method was used to enquire about food consumption by the mother and her youngest child. All foods containing vitamin A were classified into five categories: high-vitamin A animal foods (> 250 RE/100 g), low-vitamin A animal foods (< 250 RE/100 g), high-vitamin A plant foods (> 250 RE/100 g), medium-vitamin A plant foods (50–250 RE/100 g), and low-vitamin A plant foods (< 50 RE/100 g). The vitamin A content was derived from Indonesian food composition tables [3–5]. In addition to categorizing foods consumed on the basis of their vitamin A content, information was also collected on serving size: small (< 25 g), medium (25–75 g) or large (> 75 g). Enumerators were supplied with a list of foods included in each of the categories and a list of household measures of foods equal to 50 g. For calculating vitamin A intake, vitamin A contents of the categories (RE/100 g) were set at 600 for high- and 150 for low-vitamin A animal foods, and at 600, 150 and 25 for high-, medium- and low-vitamin A vegetable foods, respectively. The sizes of the three portions, small, medium and large, were set at 20, 50 and 100 g, respectively.

Biochemical parameters: Between 08:00 and 12:00, blood samples were drawn, from an antecubital vein of mothers (3 ml), from the finger tip of children (200–250 µl) in waves 1, 3 and 4 and from an antecubital vein of children (3 ml) in wave 5. Haemoglobin was determined immediately with a portable instrument (Hemocue; Angelholm, Sweden). The remaining blood was centrifuged and the serum separated and transferred to two containers. The containers were stored in the dark in a portable refrigerator powered by a car's battery for a maximum of two days. The serum was then stored at –20 °C in the laboratory of Diponegoro University in Semarang until analysis of retinol at the Nutrition Research and Development Centre in Bogor. Retinol analysis was done within 3 months of blood collection by HPLC (column: Bondapak C18, Waters, Milford, MA; detector for samples of waves 1–4: Shimadzu SPD-6AV, Tokyo, Japan; detector for samples of wave 5: Waters LCM1+; standards: Sigma; solvent: Merck, Darmstadt, Germany) with methanol/water (90:10 v/v) as mobile phase ([6] for samples of waves 1–4, [7] for samples of wave 5).

Data selected for analysis: The purpose of analysis was to identify changes between the waves of data collection that could be related to the campaign, i. e. respondents' sources of information about vitamin A, consumption of eggs and vegetables, vitamin A intake and vitamin A status, and the relationships among these factors. Households from which data were included in the analyses were those for which a complete set of data was available for the variables analysed (i. e. indicators of the factors mentioned above, and ownership of a home garden, oil consumption, receipt of a vitamin A capsule by both mother and child, ownership of a latrine, parental level of educational, and breast-feeding status), except for the question about the source of eggs consumed because of many missing data (total n = 9668). Households with an exclusively breast-fed child were excluded because food consumption patterns of the child, and possibly also of the mother, would be different from the other households. A separate set of data was created for analyses pertaining to serum retinol. In addition to having data on serum retinol levels, selection was based on the same set of variables, except for the source of information about vitamin A.

After exclusion of subjects with incomplete data sets, the following proportions of subjects were available for rounds 1, 2, 3, 4 and 5: for the large data set, 74, 81, 67, 67 and 67%, respectively; for the data set related to mother's serum retinol (wave 2 excluded), 76, 75, 75 and 78%, respectively; and for the data set related to children's serum retinol (wave 2 excluded), 85, 76, 76, and 78%, respectively. The proportion of subjects included was similar for each data set. Therefore, it is not likely that a difference between waves was due to a difference in selection of subjects between waves.

Statistics: Differences among waves were tested with the χ^2-test for categorical variables, with analysis of variance (ANOVA) for continuous variables for which the histogram of observations showed a normal distribution, and with the Kruskal-Wallis test for continuous variables for which the histogram did not show a normal distribution [8]. When ANOVA or Kruskal-Wallis tests were significant, groups were compared one by one, using Bonferroni's correction for multiple comparisons or the Mann-Whitney test, respectively.

A P value < 0.05 was considered significant. All analyses were conducted with SPSS for Windows version 7.5 (SPSS, Chicago, IL).

Results

Table I shows the basic characteristics of the respondents of waves 1–5. The average age of the youngest child under 36 months was 17–18 months and ca. 83% of them were still breast-fed. Almost all mothers and fathers had received some education. A home garden was owned by 38% of the households interviewed in wave 1 and by 23–30% in waves 2–5. About 60% owned chicken. Coverage of the six-monthly distribution of high-dose vitamin A capsules was 80–89% among children 12–35 months old.

There was an increase between waves 1 and 5 in the proportion of respondents who reported to have seen or heard messages about vitamin A spread by the social marketing campaign from banners or bill boards, posters, radio, health workers and/or friends (Table II). Radio spots were mainly aired between May and July, which period corresponds with data collection waves 3 and 4.

Table I: Characteristics of the respondents by round

	Wave 1 ($n = 5201$)	Wave 2 ($n = 5783$)	Wave 3 ($n = 4852$)
Age of mother (y), mean ± SD	27.4 ± 5.9	27.5 ± 5.8	27.4 ± 5.7
Age of child (mo), mean ± SD[1]	16.5 ± 9.2^{a}	16.9 ± 9.3^{a}	18.1 ± 9.0^{b}
Breast-feeding (%)[1]	86.0	84.6	82.6
Mother's[2] / father's[2] education (%)			
None	4.7 / 3.9	4.0 / 2.8	4.3 / 2.6
Primary school	66.2 / 59.3	64.7 / 58.1	62.1 / 57.8
Junior high school	15.1 / 14.9	14.8 / 15.3	16.3 / 15.4
Senior high school	12.5 / 18.8	14.6 / 20.0	15.2 / 20.5
Higher tertiary education	1.4 / 3.1	1.9 / 3.8	2.2 / 3.6
Owning chicken (%)[2]			
None	39.3	41.5	40.8
1–5	35.1	36.2	35.4
6–10	15.4	14.9	14.7
11–20	7.2	5.3	6.4
> 20	3.1	2.1	2.7
Owning a home garden (%)[2]	37.8	29.9	26.1
Receipt of vitamin A capsule by children 12–35 mo old in distribution month (%)[2]	80.3	88.3	81.8

[1] Values with different letter are significantly different (ANOVA, $P < 0.05$, Bonferroni correction for post-hoc multiple comparisons)
[2] Significant differences between rounds (χ^2-test, $P < 0.001$)

The campaign promoted egg consumption. Figure 1 shows that the proportion of respondents who consumed the latest egg in the past week increased within 3–4 months after the start of the campaign, from 45% to 64% for children aged 3–11 months, from 78% to 92% for children aged 12–36 months, and from 80% to 92% for mothers. Because the data from waves 3–5 were almost the same, they were combined. The group of children aged 3–11 months who had never eaten an egg decreased from 46% to 29%. Almost none of the children aged < 3 months had been given eggs and that situation did not change between the waves (data not shown). Because maternal education level is a good indicator of socio-economic status in this population [9], it was used to analyse the relationship between egg consumption and socio-economic status. The proportion of mothers who had consumed an egg in the past week was lower with lower socio-economic status (Figure 2), but egg consumption increased in all socio-economic groups. Additional analyses (not shown) revealed that egg consumption and its increase

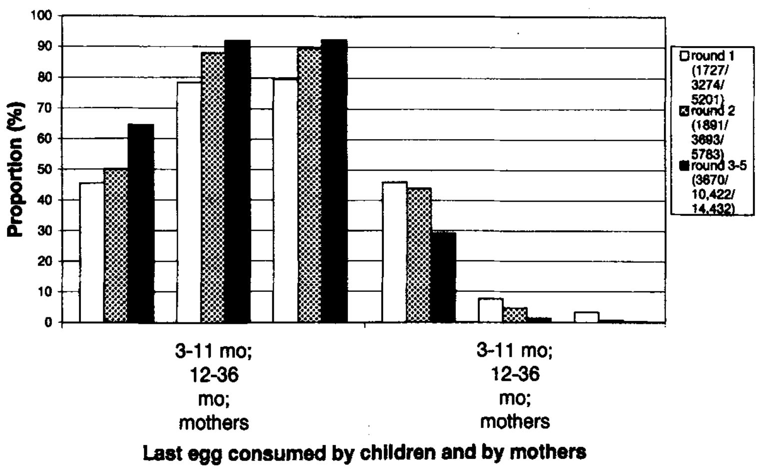

Figure 1: Consumption of latest egg by children and by mothers, by wave. In parenthesis in the legend: the number of children 3–11 months old, children 12–36 months old and mothers, respectively. Note that the category of latest egg consumed more than a week ago is not shown. For all three groups, differences in egg consumption between waves were significant ($P < 0.001$, χ^2-test).

Appendix 4

Table II: Source of information about vitamin A by wave

Source of information from each source[1] (%)	Wave 1 (n = 5201)	Wave 2 (n = 5783)	Wave 3 (n = 4852)	Wave 4 (n = 4773)	Wave 5 (n = 4807)
Health worker	74.6	80.1	84.5	85.5	78.3
Doctor	29.1	25.6	25.1	23.3	20.3
School	50.4	52.8	56.9	54.7	50.6
Friend	51.3	71.0	71.0	74.5	77.4
Radio	23.2	17.7	32.6	32.0	24.6
Poster	17.9	16.1	23.1	36.8	28.1
Banner / billboard	2.9	1.2	23.8	46.5	39.0

[1] Differences between rounds were significant ($P < 0.001$, χ^2-test)

were not related to ownership of chickens and that most eggs had been purchased (80% of the households in wave 1 and 73% in wave 5). For households that owned more than five chickens, the proportion of those for whom own production was the primary source of eggs increased from 26% in wave 1 to 41% in wave 5.

The campaign also promoted vegetable consumption. As shown in Figure 3, the amount of vegetables prepared per person per day in the past three days increased between waves 1 and 5. The median increased from 93 to 111 g/day per person. Assuming 20–30% loss after cleaning, the amount consumed thus increased from ca. 65 to 80 g/day. Additional analyses showed that 86–96% of the households had obtained some of the vegetables prepared in the past 3 days by purchasing, while 13–24% had obtained some from the garden (data not shown).

Data on vitamin A intake were collected in all rounds, but those from wave 1 were discarded because the enumerators appeared not yet skilled enough to collect them. Figure 4 shows that mothers' total vitamin A intake increased between waves 2 and 5. The same pattern was found for children (data not shown). Mothers' median vitamin A intake increased from 335 to 371 RE/d ($P < 0.001$, Mann-Whitney U-test), while that of children increased from 130 to 160 RE/d ($P < 0.001$, Mann-Whitney U-test). The intake of both plant- and animal-derived vitamin A increased (data not shown).

The first part of Table III shows that serum retinol levels of children and mothers were higher after the start of the campaign (waves 3–5) than before (wave 1). The most important question now is whether the increase in vitamin A status was related to changes in food consumption promoted by the social marketing campaign.

Mothers and children who had consumed their latest egg more recently tended to have higher serum retinol levels (second part of Table III). This trend also existed within different categories of education level, reflecting socio-economic status (Table IV). Especially for those with a lower socio-economic status more recent egg consumption was associated with a higher

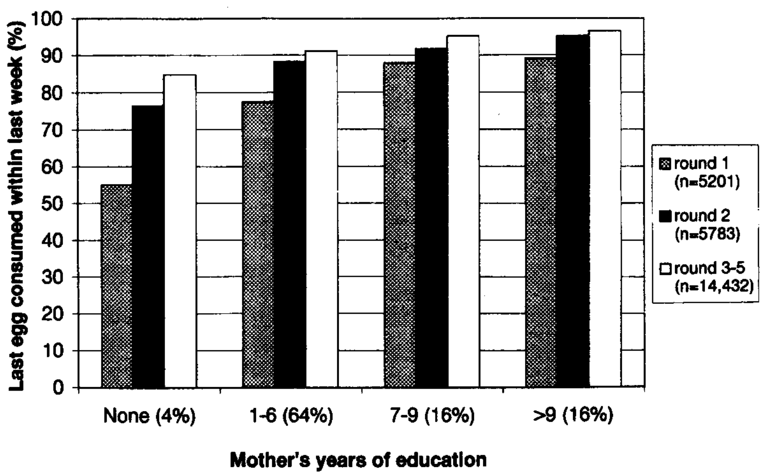

Figure 2: Proportion of mothers who had consumed the latest egg within the past week by education level and by wave. In parenthesis: at the x-axis the approximate proportion within each category (for precise numbers per round, see Table I). Within each category, differences among the rounds were significant ($P < 0.001$, χ^2-test).

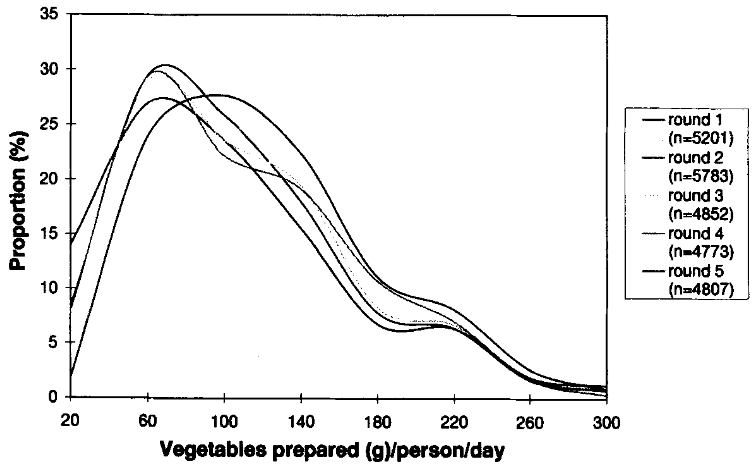

Figure 3: Households' preparation of vegetables in the past three days by wave. Waves with a different letter were significantly different from each other wave: wave 1a, 2b, 3bc, 4c, 5d ($P < 0.001$, Kruskal Wallis test and $P < 0.05$, Mann-Whitney test).

serum retinol level. Children who had received a high-dose vitamin A capsule had a higher serum retinol level than those who had not (0.92 vs. 0.86 µmol/l, $P < 0.05$), while the trend of having a higher serum retinol level when the latest egg had been consumed more recently still existed (Table V). The relationship between egg consumption and serum retinol was less clear for the children who had not received a vitamin A capsule.

Because it has previously been reported that plant vitamin A intake should be corrected to ca. 16% because of the lower bioavailability of dietary carotenoids [9, 10], total vitamin A intake was recalculated (animal vitamin A + 16% of vegetable vitamin A) before examining its relationship with serum retinol level. The median of the recalculated vitamin A intake increased between waves 2 and 5, from 102 to 120 RE/d for mothers ($P < 0.001$, Mann-Whitney U-test) and from 42 to 63 RE/d for children ($P < 0.001$, Mann-Whitney U-test). The last part of Table III shows a dose-response relation between corrected vitamin A intake and serum retinol level, for mothers as well as children.

Discussion

The analyses show that the materials of the social marketing campaign had been noticed and that, for mothers as well as children, the consumption of eggs and vegetables had increased, vitamin A intake increased and serum retinol level increased, and that serum retinol was related to egg consumption as well as vitamin A intake.

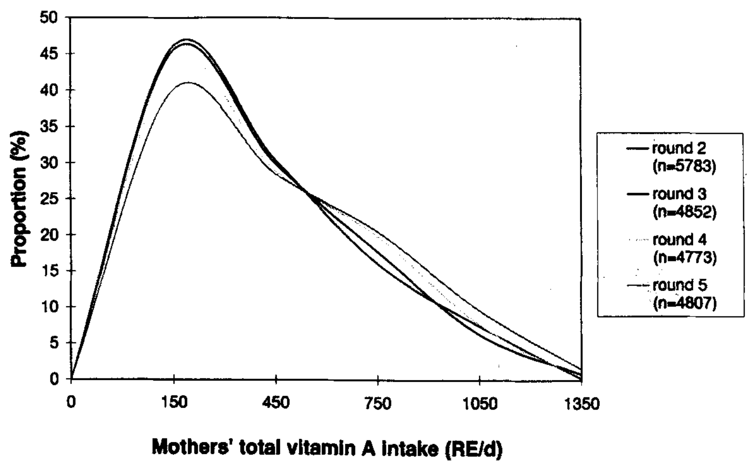

Figure 4: Mothers' total vitamin A intake by wave. Waves with a different letter were significantly different from each other wave: wave 2a, 3a, 4b, 5c ($P < 0.001$, Kruskal Wallis test and $P < 0.05$, Mann-Whitney test).

Table III: Serum retinol level (µmol/l) of children 12–23 months old and of mothers by wave, by consumption of the latest egg, and by vitamin A intake[1]

	Children 12–23 months old (n = 986)	Mothers (n = 2406)
Waves 1–5		
Wave 1	0.68 [0.63–0.73] (97) a[2]	1.08 [1.05–1.12] (296) a[2]
Wave 3	0.98 [0.93–1.02] (161) c	1.30 [1.27–1.33] (468) b
Wave 4	0.97 [0.93–1.00] (371) c	1.34 [1.31–1.36] (796) bc
Wave 5	0.87 [0.83–0.90] (357) b	1.37 [1.34–1.40] (846) c
Consumed latest egg		
Never	0.80 [0.67–0.93] (29)	1.06 [0.95–1.18] (26) a[3]
> 7 d ago	0.86 [0.79–0.94] (76)	1.24 [1.19–1.29] (217) ab
4–7 d ago	0.87 [0.83–0.91] (212)	1.32 [1.29–1.35] (596) bc
1–3 d ago	0.92 [0.88–0.95] (321)	1.31 [1.28–1.33] (820) bc
< 24 h ago	0.93 [0.89–0.96] (348)	1.34 [1.31–1.36] (747) c
Quintiles of corrected Vitamin A intake (RE/d)[5], children / mothers		
≤ 20 / < 52.5	0.86 [0.82–0.91] (211) a[4]	1.26 [1.23–1.30] (487) a[3]
> 20 – < 40 / 52.5–91	0.88 [0.84–0.93] (187) ab	1.29 [1.25–1.32] (475) a
40 – < 70 / > 91– < 133	0.89 [0.84–0.94] (192) ab	1.33 [1.29–1.36] (468) ab
70 – < 117 / 133 – < 187	0.91 [0.86–0.96] (197) ab	1.30 [1.27–1.33] (471) a
≥ 117 / ≥ 187	0.97 [0.92–1.03] (199) b	1.37 [1.34–1.41] (505) b

[1] mean [95% CI] (n)
a,b,c Groups with a different letter were significantly different from each other (ANOVA with Bonferroni correction for post-hoc multiple comparisons)
[2] ANOVA for differences among the four groups, $P < 0.001$
[3] ANOVA for differences among the five groups, $P < 0.001$
[4] ANOVA for differences among the five groups, $P < 0.05$
[5] Vitamin A intake recalculated to account for lower bioavailability of vitamin A from plant sources: vitamin A from animal foods + 16% of vitamin A from plant foods (see [9, 10])

Messages were spread using mass media such as radio, banners, billboards and posters, as well as materials for face-to-face communication. Previous campaigns focusing on vitamin A had also used these materials, except for billboards and banners. The sharp increase between waves 2 and 3 in the proportion of respondents who had seen or heard about vitamin A from billboards, banners, radio and posters indicates that the mass media spreading the messages of this campaign had been noticed. The modest increase in messages heard from health workers and friends may have been mediated by face-to-face materials.

Egg consumption increased right after the start of the campaign and was maintained till at least December 1996. The increase occurred in all socio-economic groups and was independent of ownership of chicken, but the consumption of home-produced eggs was higher in later waves. Because egg consumption increased so rapidly and in all socio-economic groups, we conclude that this was attributable to the campaign.

The amount of vegetables prepared per day increased gradually between waves 1 and 5. The data show that there was very little seasonality in consumption of vegetables. Because vegetables are considered cheap, the increase in their consumption is not likely to be a consequence of a change in price, but rather is attributable to the campaign.

Table IV: Mother's serum retinol level (µmol/l) by consumption of latest egg within categories of number of years of education[1]

Consumed latest egg	None (n = 122)	1–6 years (n = 1573)	7–9 years (n = 380)	> 9 years (n = 331)
Never	1.00 [–0.21–2.21] (3)	1.05 [0.90–1.20] (16) a	1.15 [0.90–1.39] (4)	1.08 [0.00–2.16] (3)
> 7 d ago	1.19 [1.05–1.32] (26)	1.22 [1.16–1.28] (160) ab	1.41 [1.22–1.60] (17)	1.39 [1.19–1.59] (14)
4–7 d ago	1.23 [1.10–1.37] (35)	1.31 [1.27–1.35] (439) c	1.40 [1.32–1.48] (71)	1.34 [1.24–1.44] (51
1–3 d ago	1.38 [1.18–1.58] (37)	1.28 [1.25–1.32] (538) bc	1.31 [1.25–1.36] (145)	1.40 [1.24–1.47] (100)
< 24 h ago	1.35 [1.19–1.51] (21)	1.32 [1.28–1.35] (420) c	1.30 [1.23–1.36] (143)	1.42 [1.36–1.49] (163)

[1] mean [95% CI] (n)
a,b,c Groups with a different letter were significantly different from each other (ANOVA, $P < 0.01$, Bonferroni correction for post-hoc multiple comparisons)

Vitamin A intake increased between waves 2 and 5. If data had been available for wave 1, the observed increase of intake between before and after the start of the campaign might have been larger because the consumption of both eggs as well as vegetables had already increased between waves 1 and 2.

But, before concluding that consumption changed, we should consider whether the respondents' answers reflected the real situation, or that answers were given which respondents thought the enumerators would like to hear. First of all, the enumerators presented themselves as interested in health and nutrition in general, so there was no suggestion of a link between their activities and the social marketing campaign. Secondly, households were never visited twice, thus respondents could not prepare their answers. Thirdly, the questions about food consumption were not posed very directly. For vegetable consumption, respondents were asked whether vegetables had been prepared in the past three days and, if so, how much was purchased, taken from the garden, gathered etc. This information was used to calculate the amount prepared per person per day. For vitamin A intake, a 24 h recall questionnaire was administered, which was afterwards coded for vitamin A intake. The question about consumption of the latest egg was asked amidst questions on health, and the answers obtained suggest that the respondents told the truth. Fourthly, while the various types of information about food consumption was collected in different ways, they all showed the same picture: an increase in egg consumption, an increase in amount of vegetables prepared, an increase in animal vitamin A intake, and an increase in plant-derived vitamin A intake. Thus, the campaign seems to have been effective in changing the consumption of both eggs and vegetables.

Serum retinol levels found after the start of the campaign were higher than those before its start. First, we should examine whether the serum retinol levels measured could be compared between the waves, and then we have to examine whether the increase in serum retinol level was due to the campaign.

As mentioned in the subjects and methods section, coverage of blood collection was low in wave 1, better in wave 3 and good in waves 4 and 5. A possible selection bias was most likely towards the better educated who are likely to have higher serum retinol levels. In that case, when vitamin A status did not change and a larger proportion of people with a lower nutritional status were included in later waves, serum retinol levels should have been lower in later waves. Thus, the observed increase in serum retinol levels is likely to be a real increase unless laboratory performance differed across waves. Conditions of transport and storage of samples were the same for all waves. Samples were analysed within a few months after collection. The method used to analyse the samples did not change between waves 1 and 4 and standards used were the same. Therefore, it is unlikely that there was a systematic difference in results obtained for waves 1, 3 and 4. Samples from wave 5 were analysed with a new HPLC system (Waters LCM1 with auto-sampler and a photodiode array detector), for which the method was introduced by the University of Ulster, Coleraine, UK [7]. Standards used were the same as those used for waves 1–4. For mothers, the gradual increase in serum retinol levels seen

Table V: Children's (12–23 mo old) serum retinol level (µmol/l) by consumption of latest egg within categories of receipt of a high-dose vitamin A capsule in past 6 months[1]

Consumed latest egg	Received vitamin A capsule in past six months (n = 673)	Did not receive vitamin A capsule in past six months (n = 313)
Never	0.84 [0.62–1.06] (13)[2]	0.77 [0.60–0.94] (16)[2]
> 7 d ago	0.86 [0.77–0.95] (49)	0.88 [0.72–1.03] (27)
4–7 d ago	0.88 [0.83–0.93] (139)	0.86 [0.79–0.92] (73)
1–3 d ago	0.93 [0.88–0.98] (214)	0.88 [0.82–0.94] (107)
< 24 h ago	0.95 [0.91–0.99] (258)	0.86 [0.79–0.93] (90)

[1] mean [95% CI] (n)
[2] Differences between groups in one column were not significant (ANOVA)

between waves 3 and 4 was also seen between waves 4 and 5. For children, serum retinol levels were lower in wave 5 than in waves 3 and 4, which may have been due to the change in the way their serum was obtained. Until wave 4, blood was collected from the finger, using capillary tubes ($5 \times 50\ \mu l$) in which it was also stored until centrifugation and separation of serum in the field laboratory. In wave 5, blood was obtained by venipuncture (3 ml) and stored in a covered tube until processing. Blood kept in capillary tubes may have been more subject to evaporation than blood kept in the larger tubes, causing a slight increase in retinol levels in serum of waves 1–4 relative to wave 5. Thus, while serum retinol levels found for children in waves 1–4 may have been slightly exaggerated due to evaporation, serum retinol levels of mothers and children seem to have increased between rounds 1 and 5.

Serum retinol levels were related to egg consumption. For mothers, the relationship was significant and remained when controlled for socio-economic status. For children, the same trend was found and it was also seen when controlled for receipt of a vitamin A capsule. Although not all relationships were significant, the same trends were observed for mothers and children and within their respective subgroups. In addition, because data on egg consumption only concerned consumption of the latest egg, misclassification of some subjects may have reduced the contrast between the groups. Subjects who did not consume eggs very regularly could have been classified in a category of recent egg consumption if they had consumed their latest egg very recently. Thus, it is valid to conclude that there was a positive relationship between egg consumption and serum retinol in mothers as well as in children. A positive relationship was also found between vitamin A intake and serum retinol level both in mothers and in children.

Based on the observations that 1. vitamin A status was higher after the start of the campaign, 2. vitamin A status was related to consumption of eggs and intake of vitamin A, also when controlled for socio-economic status and for receipt of a vitamin A capsule, and 3. consumption of both eggs and vegetables increased after the start of the campaign, we conclude that the campaign was effective in improving vitamin A status by increasing the consumption of vitamin A-rich foods.

At least half of the success of the campaign in Central Java can be attributed to the promotion of eggs. Before the start of the campaign, the proportions of mothers who had consumed an egg within the past 24 h, 1–3 d ago and 4–7 d ago were as high as 39%, 27% and 14%, respectively, indicating that eggs were already commonly consumed. But the campaign succeeded in increasing consumption even further, especially by reducing the proportion of those who had consumed the latest egg more than a week ago or never.

This is the first social marketing campaign for which an impact on vitamin A status has been documented. Most campaigns have only been evaluated for their impact on knowledge, attitude and practice. The only other documented campaign that evaluated changes in vitamin A status, promoted very successfully the production and consumption of one particular vitamin A-rich vegetable, ivy gourd, but did not find a conclusive result as to an impact on vitamin A status [2].

This evaluation is also an example of how useful a nutritional surveillance system can be for evaluating the impact of a health or nutrition programme. In Bangladesh, the role of the vitamin A capsule distribution programme for combating vitamin A deficiency has been evaluated on the basis of nutritional surveillance data collected in 1990–1994 [11]. In Central Java, nutritional surveillance has been continued in June 1998 to monitor the impact of Indonesia's current economic crisis on household food security, nutritional status and health.

In conclusion, where availability, affordability and acceptance allow, the consumption of animal sources of vitamin A, such as eggs, should be promoted for improving vitamin A status. Egg consumption had an impact on children's vitamin A status in addition to the distribution of high-dose vitamin A capsules. For other groups that are vulnerable to vitamin A deficiency but cannot or do not receive a high-dose vitamin A capsule, such as pregnant women, most of breast-feeding women, adolescent girls and school children, the combined increase in vitamin A intake from vegetable and animal sources is a realistic way of improving vitamin A status. Where fortified foods can be introduced, they are likely to further increase the effectiveness of a food-based approach.

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Reappraisal of the role of vegetables in the vitamin A status of mothers in Central Java, Indonesia[1–3]

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ABSTRACT Food-based approaches for controlling vitamin A deficiency and its consequences, such as increased mortality, more severe morbidity, and anemia, have become increasingly important, thus prompting a reassessment of the relation between vitamin A intake and status. A nutrition surveillance system in Central Java, Indonesia, assessed the vitamin A intake and serum retinol concentration of women with a child ≤24 mo old with a semiquantitative 24-h recall method that categorized vitamin A–containing foods into 3 categories of plant foods and into 2 categories of animal foods and identified portions as small, medium, or large. Median vitamin A intake was 335 retinol equivalents (RE)/d (n = 600) and vitamin A intake from plant foods was 8 times higher than from animal foods. Serum retinol concentration was related to vitamin A intake in a dose-response manner. The multiple logistic regression model for predicting the chance for a serum retinol concentration greater than the observed median (≥1.37 µmol/L) included physiologic factors, vitamin A intake from plant [odds ratio (95% CI) per quartile: 1st , 1.00; 2nd, 1.23 (0.75, 2.02); 3rd, 1.60 (0.97, 2.63); and 4th, 2.06 (1.25, 3.40)] and animal [1st and 2nd, 1.00; 3rd, 1.31 (0.86, 2.02); and 4th, 2.18 (1.40, 3.42)] foods, home gardening [(no, 1.00; yes, 1.71 (1.12, 2.60)], and woman's education level [≤primary school, 1.00; ≥secondary school, 1.51 (1.02, 2.22)]. Despite the fact that plant foods contributed 8 times as much vitamin A as did animal foods, serum retinol concentrations did not reflect this large difference. Home gardening and woman's education level seemed to reflect longer-term consumption of vitamin A–rich plant and animal foods, respectively. *Am J Clin Nutr* 1998;68:1068–74.

KEY WORDS Vitamin A intake, plant foods, animal foods, 24-h recall, vitamin A status, home gardening, socioeconomic status, maternal health, Indonesia, humans, women

INTRODUCTION

Vitamin A deficiency has severe consequences, such as increased mortality among women (1) and children (2), more severe morbidity of longer duration (3), and anemia that only partly responds to iron supplementation (4, 5). Therefore, one of the goals set for the year 2000 at the World Summit for Children in 1990 was the virtual elimination of vitamin A deficiency. As a result, many countries are now implementing programs to control vitamin A deficiency. These programs often include periodic dosing of children aged <5 y with high-dose vitamin A capsules for the short-term, whereas food-based approaches are being developed for the longer-term. The effectiveness of food-based programs should be evaluated by periodic monitoring of vitamin A intake, vitamin A status, morbidity and mortality, and the relations among these indicators.

However, such a comprehensive and interactive evaluation has been limited until now by, among others, the difficulties in collecting data on dietary vitamin A intake that are related to vitamin A status (6). One reason for this could be that the bioavailability of carotenoids from fruit and vegetables appears to be much lower than assumed previously (7, 8). The consequence of this lower bioavailability may be that, until now, vitamin A intake from fruit and vegetables, but not from animal foods, has been overestimated. If this is the case, it becomes important to distinguish between plant and animal foods when collecting data on dietary vitamin A intake.

We examined whether distinguishing between plant and animal sources of vitamin A improves the relation between data on vitamin A intake and vitamin A status in a cross-sectional format. Other factors that can affect this relation, such as physiologic factors, socioeconomic status, and ownership of a home garden, are also included in the analysis. The data used were obtained from women with a child aged ≤24 mo and were collected by the nutrition surveillance system that was set up to monitor the effect of a province-wide social marketing campaign in the Indonesian province of Central Java. The campaign for the improvement of vitamin A status of the population was started in April 1996 and promotes the consumption of vitamin A–rich foods, especially eggs and dark-green, leafy vegetables.

[1] From Helen Keller International, Jakarta, Indonesia; the Micronutrient Initiative, Kathmandu, Nepal; Diponegoro University, Semarang, Indonesia; UNICEF, Beijing; UNICEF, New York; and the Nutrition Research and Development Centre, Bogor, Indonesia.

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Appendix 5

SUBJECTS AND METHODS

Subjects and sampling design

The social marketing campaign involves the entire population of Central Java province. In the period June-August 1996, the third round of data collection of the Central Java nutrition surveillance system collected cross-sectional data on socioeconomic status, food production, food consumption, vitamin A intake, anthropometry, and morbidity from a total of 7196 households with a child aged ≤36 mo. Sampling of households was done according to a multistage cluster design. Central Java consists of 6 ecologic zones. From each zone, 30 villages were selected by probability proportional to size sampling. Each village provided a list of households with a child aged ≤36 mo. From this list, 40 households were selected by interval sampling using a random start. For example, if 1000 households were listed, every 25th household (1000/40 = 25) on the list was selected and the first household was randomly selected from the first 25. Selected households would then, for example, be number 10, 35, 60, 85, 110, etc.

From each zone, a subsample of 6 villages was randomly selected for blood collection from the women and their youngest child for the measurement of hemoglobin and serum retinol concentrations. Households were selected for blood collection if they were included in the sample frame and had a child aged ≤24 mo (n = 1134). Written, informed consent was obtained before blood collection. This procedure for blood collection was approved by the Medical Ethical Committee of the Indonesian Ministry of Health. Data from the women included in the subsample for blood collection are reported in this paper.

General questionnaire

The general questionnaire collected information on household composition, educational background of the parents, occupation of the main earner, sanitary conditions, livestock ownership, knowledge about vitamin A and the source of such knowledge, household consumption of oil and coconuts, and source, preparation, and consumption of vegetables. In addition, anthropometric measurements were made and data on vitamin A intake and morbidity were collected from the woman and her youngest child (<36 mo). All data were collected by graduates from Indonesian schools of dietetics.

Anthropometry

Weight was measured to the nearest 0.1 kg with a UNICEF scale. Height was measured to the nearest 0.1 cm with a microtoise. Midupper arm circumference was measured to the nearest 0.1 cm with a measuring tape distributed by the Indonesian Ministry of Health.

Vitamin A intake

The women were interviewed about food consumption during the previous 24 h. All foods that contained vitamin A were classified into 5 categories: high–vitamin A animal foods [>250 retinol equivalents (RE)/100 g], low–vitamin A animal foods (<250 RE/100 g), high–vitamin A plant foods (>250 RE/100 g), medium–vitamin A plant foods (50–250 RE/100 g), and low–vitamin A plant foods (<50 RE/100 g). The vitamin A content was taken from Indonesian food-composition tables (9–11). In these tables, the carotene content had already been converted into retinol equivalents by using conventional conversion factors. In addition to categorizing foods consumed based on their vitamin A content, information was also collected on the portion sizes: small (<25 g), medium (25–75 g), or large (>75 g). The fieldworkers were equipped with a list of foods included in each of the categories and a list of household measures of foods equal to 50 g. For calculating vitamin A intake, the vitamin A content of the categories (RE/100 g) was set at 600 for high– and 150 for low–vitamin A animal foods, and at 600, 150, and 25 for high–, medium–, and low–vitamin A plant foods, respectively. The size of the 3 portions (ie, small, medium, and large) was set at 20, 50, and 100 g, respectively.

Biochemical indexes

Between 0800 and 1200, blood samples (3 mL) were drawn from an antecubital vein of each subject. The hemoglobin concentration was analyzed immediately with the Hemocue device (Hemocue, Angelholm, Sweden). At the location of blood collection, the remaining blood was centrifuged at 750 × g for 10 min at room temperature and the serum was separated and stored in 2 containers. The containers were kept in the dark in a portable refrigerator operated by a car's cigarette lighter for a maximum of 2 d. After that, serum was stored at −20°C in the laboratory of Diponegoro University in Semarang until retinol was analyzed at the Nutrition Research and Development Centre in Bogor. Analysis was done within 3 mo of blood collection by HPLC (Bondapak C_{18} column: Waters, Milford, MA; detector: Shimadzu SPD-6AV, Tokyo; standards: Sigma Chemical, St Louis; solvent: Merck, Darmstadt, Germany) with methanol:water (90:10, by vol) as mobile phase (12).

Statistics

To determine what factors were related to serum retinol concentration, data were analyzed as follows. First, the relation between serum retinol concentration and vitamin A intake from plant and animal foods was assessed. Then, the association between the serum retinol concentration and physiologic factors, socioeconomic status, vegetable production, and receipt of a vitamin A capsule was determined. Vitamin A intake and all other indexes that had been found to be related to serum retinol concentration were then available for entry into a multivariate model of factors determining the serum retinol concentration. For the nonphysiologic factors that entered this multivariate model, the relation with vitamin A intake from plant and animal foods was determined.

Statistical tests used for the analyses were as follows. For variables of which the histogram of observations showed a normal distribution, differences among groups were examined by analysis of variance (ANOVA). For variables without such a normal distribution, differences among groups were examined by the Kruskal-Wallis test for >2 groups and by the Mann-Whitney U test for 2 groups. Spearman rank-order correlation coefficients were calculated to assess the association between variables without a normal distribution. Multiple logistic regression analysis was used to determine which factors were most important for predicting whether a woman had a serum retinol concentration above the observed median value of the population. For those factors, odds ratios are reported with 95% CIs. A P value <0.05 was considered significant. All analyses were conducted by using SPSS for Windows (version 7.5; SPSS Inc, Chicago).

RESULTS

From the 1134 women selected for blood collection, 623 provided a blood sample (55%). The coverage per village ranged from

32% to 93%. Data are reported for the 600 women for whom complete data were available. A few of the indexes reported in this article were different between the women in the subsample (n = 600) and the other women selected for blood collection (n = 534): the women in the subsample had a younger child (mean: 10.8 compared with 12.7 mo), a lower body weight (47.7 compared with 48.8 kg), and a smaller midupper arm circumference (24.4 compared with 24.7 cm). This subsample also had indexes that were different from the total group of women not included in the subsample (n = 6595): they had a younger child (mean: 10.8 compared with 11.7 mo), a lower body weight (47.7 compared with 48.6 kg), and a smaller stature (1.49 compared with 1.50 m), and fewer of them had a home garden (22% compared with 27%). However, it is unlikely that these indexes affect the relation between vitamin A intake and serum retinol concentration. Therefore, the differences between the women in the subgroup and the other women are not expected to affect the conclusions drawn in this paper.

Some general characteristics of the women are shown in **Table 1**. Body mass index (in kg/m^2) was <18.5 for 15% and >27 for 5% of the women. The mean serum retinol concentration was 1.33 μmol/L, whereas the median dietary vitamin A intake was 335 RE/d. Vegetables and fruit provided 89% and animal foods provided 11% of the dietary vitamin A intake. There was a dose-responsive relation between dietary vitamin A intakes and serum retinol concentrations (**Table 2**). The Spearman rank-order correlation between vitamin A intake and the serum retinol concentration was 0.15 (P < 0.001).

Serum retinol concentrations of women by vitamin A intake from plant and animal foods below or above the median are shown in **Table 3**. A dose-responsive relation was found between the serum retinol concentration and vitamin A intake from both plant foods and animal foods. For vitamin A intake from animal foods, the relation was also found within the 2 groups for vitamin A intake from plant foods. The Spearman rank-order correlation between vitamin A intake from plant foods and the serum retinol concentration was 0.09 (P < 0.05) and between vitamin A intake from animal foods and the serum retinol concentration was 0.16 (P < 0.001). Vitamin A intakes from plant and animal foods were negatively correlated (Spearman rank-order correlation: $\rho = -0.11$, P < 0.05).

Blood was not collected from clinically ill women. On the day of data collection, the prevalence of diarrhea among the women was 0.3% and their body temperature was normal (35.9–37.6 °C). Because of this low prevalence of infection and the lack of information on parasitic infestation, data were not analyzed for the relation between infection and vitamin A intake or vitamin A status. However, for indicators of the physiologic condition, food production, and socioeconomic status, the relation with serum retinol concentration was evaluated. The bivariate relation for the indicators that were significantly related to serum retinol concentration are shown in **Tables 4** and **5**. In addition, examination of the relation between breast-feeding status and age of the youngest child showed significant differences in mean age: 3.8, 11.4, and 16.7 mo for exclusive breast-feeding, supplemented breast-feeding, and not breast-feeding, respectively. Indicators that showed no significant correlation with serum retinol concentration were height, body mass index, and age of the mother. Thus, in addition to vitamin A intake from plant and animal foods, the woman's serum retinol concentrations were also related to physiologic factors, such as breast-feeding status, age of the youngest child, midupper arm circumference, weight, and hemoglobin concentration; receipt of a vitamin A capsule after delivery of the youngest child; fruit and vegetable production, evidenced by ownership of a home garden; and socioeconomic factors, such as house size, education level of the woman, education level of her husband, and use of a closed latrine.

Of the indicators that were examined for their relation with serum retinol concentrations, house size (Spearman rank-order correlation: ρ = 0.19, P < 0.001) and ownership of a home garden (P < 0.05, Mann-Whitney U test) were found to be positively related to vitamin A intake from plant sources; height (ρ = 0.09, P < 0.05), weight (ρ = 0.10, P < 0.05), the woman's and her husband's education level (P < 0.001, Kruskal-Wallis tests), use of a closed latrine (P < 0.001, Mann-Whitney U test), and receipt of a vitamin A capsule after delivery (P < 0.01, Mann-Whitney U test) were found to be positively related to vitamin A intake from animal sources.

To determine which factors were most strongly associated with serum retinol concentrations, logistic regression analysis was performed for the chance that a woman had a serum retinol concentration above the observed median of the population (≥1.37 μmol/L). Variables available for stepwise entrance into the logistic regression model were vitamin A intake from plant and animal foods, factors related to serum retinol concentrations (Tables 4 and 5), factors related to vitamin A intake from plant and animal sources (*see* preceding paragraph), age of the mother, and body mass index. Vitamin A intake from plant and animal foods was divided into quartiles to examine the dose-responsive relation (the first 2 quartiles of vitamin A intake from animal foods were combined because 41% of the women did not consume animal foods containing vitamin A). The education level of

TABLE 1
Characteristics of the women with a child ≤24 mo old[1]

Age (y)	27 ± 6[2]
Age of child (mo)	11 ± 6
Height (m)	1.49 ± 0.05
Weight (kg)	47.7 ± 7.2
Body mass index (kg/m^2)	20.9 (18.0–25.2)[3]
Midupper arm circumference (cm)	24.4 ± 2.6
Serum retinol (μmol/L)	1.33 ± 0.33
Vitamin A from plant foods (RE/d)	279 (25–650)
Vitamin A from animal foods (RE/d)	30 (0–150)
Total dietary vitamin A intake (RE/d)	335 (63–750)
Proportion of vitamin A from plant foods (%)	89 (25–100)
Proportion of vitamin A from animal foods (%)	11 (0–75)

[1] n = 600. RE, retinol equivalents.
[2] $\bar{x}$ ± SD.
[3] Median; 10th–90th percentiles in parentheses.

TABLE 2
Woman's serum retinol concentrations by quartile of dietary vitamin A intake[1]

Vitamin A intake (RE/d)	Serum retinol concentration
	μmol/L
1st Quartile, ≤140	1.27[a] (1.22, 1.32) [150]
2nd Quartile, 141–336	1.32[a] (1.27, 1.37) [151]
3rd Quartile, 336–537	1.34[a,b] (1.28, 1.40) [149]
4th Quartile, >537	1.39[b] (1.34, 1.45) [150]

[1] Mean; 95% CI in parentheses and n in brackets. RE, retinol equivalents. Means with different superscript letters are significantly different, P < 0.05 (ANOVA, post hoc multiple comparisons test of least significant difference).

TABLE 3

Serum retinol concentrations by vitamin A intake from plant and animal foods below or above the median[1,2]

Vitamin A from plant foods	Vitamin A from animal foods		
	Below median, <50 RE/d	Above median, ≥50 RE/d	Total, 0–600 RE/d
		μmol/L	
Below median, <280 RE/d	1.26 (1.21–1.30) [159]	1.35 (1.31–1.40) [141]	1.30 (1.27–1.34) [300]
Above median, ≥280 RE/d	1.31 (1.25–1.37) [152]	1.40 (1.35–1.46) [148]	1.36 (1.32–1.40) [300]
Total, 0–1563 RE/d	1.28 (1.25–1.32) [311]	1.38 (1.35–1.42) [289]	1.33 (1.30–1.36) [600]

[1] Mean; 95% CI in parentheses and *n* in brackets. RE, retinol equivalents. Overall ANOVA, $P < 0.01$. Main effects of animal vitamin A, $P < 0.001$; plant vitamin A, $P < 0.05$; interaction, NS.

the women and their husbands was divided into 2 categories to increase distinguishing power. For house size, the natural logarithm was taken because of its skewed distribution. Because breast-feeding status was related to age of the breast-fed child, and ownership of a home garden to house size, interaction terms for these variables were also available for entrance into the model. The logistic regression model for the chance of having a serum retinol concentration above the median of the population is shown in **Table 6**. Because the interaction term of breast-feeding status and age of the child came into the model, the analysis was rerun with "forced entrance" for the variables that entered the model when the analysis was run stepwise, with the addition of breast-feeding status and age of the child. This resulted in nonsignificance for the variables breast-feeding status, age of the child, and their interaction term. When the *P* value for stepwise entrance into the logistic regression model was extended to <0.10, the woman's age and woman's education level were also entered into the model.

The factors included in the model (Table 6) were indicators of physiologic status (age of the youngest child, breast-feeding status, age of the woman, and hemoglobin concentration); vitamin A intake from plant and animal foods; and factors that seem to be related to vitamin A status as well as to vitamin A intake (ownership of a home garden and woman's education level). Other variables that had been found to be related to vitamin A intake or to vitamin A status in bivariate analyses did not enter the logistic regression model.

For ownership of a home garden and woman's education level, the relation with vitamin A intake during the previous 24 h from plant and animal foods was examined for all women, regardless of whether their blood sample was collected (**Table 7**). Analysis of data from the subsample of women ($n = 600$) showed the same trends (data not shown). Women with a home garden had a higher vitamin A intake from plant foods and a lower vitamin A intake from animal foods than women without a home garden. The higher a woman's education level, the higher her vitamin A intake from animal foods; however, her vitamin A intake from plant foods was not different. Ownership of a home garden and woman's education level were negatively correlated ($P < 0.001$, chi-square test).

TABLE 4

Bivariate relation between the women's serum retinol concentration and various categorical variables[1]

	Serum retinol concentration
Breast-feeding	
Exclusive	1.44 (1.37–1.52)[b] [77]
With supplementary food	1.31 (1.28–1.34)[a] [485]
Not breast-feeding	1.39 (1.30–1.48)[a,b] [38]
Women's education	
None	1.32 (1.20–1.43)[a,b] [28]
Primary school	1.29 (1.26–1.33)[a] [382]
Junior high school	1.38 (1.31–1.45)[a,b] [91]
Senior high school	1.44 (1.36–1.51)[b] [83]
Higher tertiary education	1.44 (1.28–1.60)[a,b] [16]
Husband's education	
None	1.39 (1.27–1.51)[a,b] [22]
Primary school	1.30 (1.26–1.33)[a] [351]
Junior secondary school	1.33 (1.26–1.40)[a,b] [96]
Higher secondary school	1.39 (1.33–1.45)[a,b] [108]
Higher tertiary education	1.53 (1.43–1.63)[b] [23]
Latrine	
Closed latrine	1.38 (1.34–1.42)[a] [258]
Open latrine, river or pond side, bush, open field, other	1.30 (1.26–1.33)[b] [342]
Vitamin A capsule	
Within 3 wk after last delivery	1.41 (1.33–1.48)[b] [69]
None after last delivery	1.32 (1.29–1.35)[a] [531]
Home garden	
No	1.32 (1.28–1.35)[a] [468]
Yes	1.38 (1.33–1.44)[b] [132]

[1] Mean; 95% CI in parentheses and *n* in brackets. Means within a category with different superscript letters are significantly different, $P < 0.05$ (ANOVA, Bonferroni correction for multiple comparisons).

DISCUSSION

Dietary vitamin A intake showed a dose-responsive relation with serum retinol concentration. Despite the fact that plant foods contributed 8 times as much vitamin A as did animal foods (89% compared with 11%), on the basis of conventional conversion factors, serum retinol concentrations did not reflect this large difference. Ownership of a home garden and woman's education level were positively correlated with serum retinol concentration and with vitamin A intake from plant and animal foods, respectively.

TABLE 5

Bivariate relation (Spearman's rank-order correlation coefficient) between women's serum retinol concentrations and various continuous variables[1]

	ρ	*P*
Age of child ≤24-mo old (mo)	−0.11	<0.01
Weight (kg)	0.10	<0.05
Midupper arm circumference (cm)	0.09	<0.05
Hemoglobin concentration (g/L)	0.22	<0.001
Size of house (m^2)	0.11	<0.01

[1] $n = 600$.

TABLE 6
Odds ratios and 95% CIs for having a serum retinol concentration above the median of the population (≥ 1.37 μmol/L): forward entrance into a multiple logistic regression model[1]

	Entrance into the model if			
	$P < 0.05$	P	$P < 0.10$	P
Age of child ≤24 mo (mo)	1.01 [0.95–1.07]	NS	1.01 [0.95–1.07]	NS
Breast-feeding				
Exclusive	1.00		1.00	
With supplementary food	0.65 [0.27–1.57]	NS	0.70 [0.29–1.70]	NS
Not breast-feeding	0.35 [0.04–2.77]	NS	0.35 [0.04–2.92]	NS
Age of child ≤24 mo (mo)				
Breast-feeding, exclusive	1.00		1.00	
With supplementary food	0.95 [0.81–1.10]	NS	0.93 [0.80–1.09]	NS
Not breast-feeding	1.05 [0.87–1.26]	NS	1.03 [0.86–1.25]	NS
Age of woman (y)	—	—	1.03 [1.00–1.06]	<0.10
Hemoglobin concentration (g/L)	1.03 [1.01–1.04]	<0.001	1.03 [1.01–1.04]	<0.001
Woman's education				
≤ Primary school	—	—	1.00	
≥ Secondary school	—	—	1.51 [1.02–2.22]	<0.05
Home garden				
No	1.00		1.00	
Yes	1.65 [1.09–2.51]	<0.05	1.71 [1.12–2.60]	<0.05
Vitamin A from animal foods (RE/d)[2]				
<50	1.00		1.00	
50–75	1.39 [0.91–2.13]	NS	1.31 [0.86–2.02]	NS
>75	2.47 [1.60–3.81]	<0.001	2.18 [1.40–3.42]	<0.001
Vitamin A from plant foods (RE/d)[3]				
≤60	1.00		1.00	
61–279	1.27 [0.78–2.07]	NS	1.23 [0.75–2.02]	NS
280–420	1.56 [0.95–2.56]	<0.10	1.60 [0.97–2.63]	<0.10
>420	2.11 [1.29–3.47]	<0.01	2.06 [1.25–3.40]	<0.01

[1] The logistic regression analysis was first run for stepwise entrance into the model. Because the interaction terms for breast-feeding status and child's age entered the model, the analysis was rerun with "forced entrance" of the variables that had entered the model on stepwise entrance and with inclusion of breast-feeding status and age of the breast-fed child. This altered the P values for the variables included in the model. Variables that did not enter the logistic regression models were receipt of a vitamin A capsule after the last delivery, midupper arm circumference, weight, height, body mass index, husband's education level, type of latrine used, natural logarithm of house size, and the interaction term for natural logarithm of house size, and ownership of a home garden. $n = 600$.

[2] The overall P value for vitamin A from animal foods was <0.001 for the first model and <0.01 for the second model.

[3] The overall P value for vitamin A from plant foods was <0.05 for both models.

The data collected on vitamin A intake were associated with vitamin A status. This was most clearly shown when subjects were grouped according to intake (Tables 2, 3, and 6). This grouping was necessary because the data on vitamin A intake were not reliable on an individual level because they were collected with a semiquantitative method that was based on a 24-h recall of consumption, whereas the day-to-day variation of vitamin A intake is very large (13). Therefore, several subjects will have been misclassified.

Misclassification may have been a larger problem for vitamin A intake from plant foods than from animal foods, for several reasons. Classification of vegetables into categories of low,

TABLE 7
Vitamin A intake from plant and animal foods by ownership of a home garden and woman's education level[1]

	Vitamin A intake (RE/d)		
	Plant foods	Animal foods	Total
Home garden			
No (n = 5251)	278 (56–505)[a]	60 (0–90)[b]	338 (145–600)[a]
Yes (n = 1902)	330 (89–613)[b]	30 (0–75)[a]	363 (175–625)[b]
Woman's education			
None (n = 352)	305 (50–615)[a,b]	0 (0–75)[a]	328 (125–624)[a]
Primary school (n = 4672)	320 (63–605)[b]	30 (0–75)[b]	350 (150–625)[a]
Junior high school (n = 1078)	265 (56–403)[a]	75 (0–120)[c]	331 (150–560)[a]
Senior high school (n = 947)	265 (50–385)[a]	75 (30–150)[d]	335 (175–550)[a]
Higher tertiary education (n = 142)	286 (50–376)[a,b]	150 (75–210)[e]	408 (209–628)[b]

[1] Median; 25th and 75th percentiles are in parentheses. Values for homegarden or woman's education, separately, with different superscript letters within a column are significantly different, $P < 0.05$ (Kruskal-Wallis test), followed by the Mann-Whitney U test for comparison of 2 categories, $P < 0.05$.

medium, or high vitamin A content was based on values reported in Indonesian food-composition tables (9–11). These values were based on spectrophotometric analysis of total carotene content, which is converted to vitamin A content, assuming a certain portion of provitamin A carotenoids. More recent methods, such as HPLC analysis, can quantify individual carotenoids. It has been found that the estimate of vitamin A intake from vegetables made by using data on the vitamin A content from HPLC analysis (14, 15) was 70% of that based on Indonesian food-composition tables (16). Also, within one species of vegetable, the carotene content can vary widely, depending on factors such as maturity, handling after harvest, and preparation practices (15). Because this variation reduces the precision of the estimate of intake, it can increase the misclassification of subjects into groups of intake and hence, reduces the differences in serum retinol concentration between these groups. Thus, it can be assumed that the vitamin A intake from vegetables, based on conventional conversion factors, was ≈70% of that estimated by using Indonesian food-composition tables and that the differences in serum retinol concentrations between the groups of vitamin A intake from plant foods were underestimated relative to those for animal foods.

However, even when these assumptions were correct, the vitamin A intake from plant foods was still much higher than that from animal foods, whereas the difference in serum retinol concentrations was very small. These findings are similar to those of a recent intervention trial in schoolchildren in West Java, ie, that the mean (95% CI) effectiveness of dark-green, leafy vegetables and carrots in improving vitamin A status was only 23% (8%, 46%) and of fruit was only 50% (21%, 100%) of what has been assumed until now (17).

Adjustment of the vitamin A intake from plant foods to a lower vitamin A content than that reported in Indonesian food-composition tables and to a lower effectiveness in improving vitamin A status, as shown in the West Java study, would result in values that are 16% (70% × 23%) of the originally assumed values. The finding of a greater effectiveness of fruit than of vegetables (17) did not need to be accounted for because fruit consumption in Central Java is very low between June and August. When the vitamin A intake from plant foods in the current study was adjusted for by 16%, intake quartiles became very similar to those for vitamin A intake from animal foods: eg, Table 3: <45 and ≥45 RE/d compared with <50 and ≥50 RE/d; and Table 6: <10, 10–44, 45–67, and ≥68 RE/d compared with <50, 50–75, and >75 RE/d. This is in line with the similarity of serum retinol concentrations in the corresponding quartiles of vitamin A intake from animal foods and plant foods. When total vitamin A intake was adjusted for the lower vitamin A activity of plant foods, its relation with the serum retinol concentration improved. Spearman rank-order correlation was 0.21 (P < 0.001) and serum retinol concentrations for quartiles of total vitamin A intake (≤52, 53–99, 99–153, and ≥154 RE/d) were more different from those shown in Table 2 [mean (95% CI)]: 1.25 μmol/L (1.19, 1.30), n = 150; 1.28 μmol/L (1.23, 1.33), n = 151; 1.37 μmol/L (1.31, 1.42), n = 148; and 1.43 μmol/L (1.38, 1.48), n = 151. The serum retinol concentration of the first 2 quartiles was significantly lower than that of the last 2 quartiles (ANOVA with post hoc multiple comparisons test for least significant differences).

Thus, the relation between total dietary vitamin A intake and serum retinol concentrations improved when vitamin A intake was recalculated based on adjusted vitamin A intake from plant foods. This suggests that adjustment of the vitamin A intake from plant foods to 16% was justified and lends credence to the findings of the intervention trial with schoolchildren in West Java (17).

The remainder of the analyses dealt with the relations between other measured variables as determinants of vitamin A status and mediators of vitamin A intake. The method used for assessing vitamin A intake had previously been used for nutrition surveillance in Bangladesh (18, 19) and for a national survey in Vietnam (20). Analysis of the data from Bangladesh showed a positive relation between vitamin A intake and fruit and vegetable production in home gardens and the number of varieties grown (18). Also, women with a vitamin A intake below the median had a higher risk of nightblindness and diarrhea (19). Vegetables are almost the only affordable source of vitamin A in Bangladesh. These findings thus suggest that, although vegetables may be less important for vitamin A status than once assumed, they are important for health and for vitamin A–related morbidity. An inverse relation has been reported between vitamin A intake and mortality (21). Therefore, the relation of vitamin A intake from different foods with morbidity and mortality needs to be explored.

The multiple logistic regression model for the chance of having a serum retinol concentration above the observed median of the population (≥1.37 μmol/L) included not only the vitamin A intake from plant and animal foods, but also the age of the child, breast-feeding status, age of the woman, hemoglobin concentration, ownership of a home garden, and woman's education level. The entrance of the interaction term for age of child and breast-feeding status indicated that the longer a woman breast-feeds, the lower her serum retinol concentration becomes and that it improves after she stops breast-feeding. The positive relation between concentrations of hemoglobin and serum retinol may have been related to vitamin A deficiency, which can prevent an increase in hemoglobin concentration (4, 5), and to infection, which might suppress both indexes (22). Ownership of a home garden and woman's education level were related to serum retinol concentration as well as to vitamin A intake. House size was also related both to vitamin A status and to vitamin A intake from plant sources but it did not enter the logistic regression model. It may not have entered because of its positive relation with ownership of a home garden, which did enter the model. Similarly, variables that were related both to vitamin A status and to vitamin A intake from animal sources, but that did not enter the model, were husband's education level, use of a closed latrine, receipt of a vitamin A capsule after delivering their youngest child, and weight. In addition, midupper arm circumference, which was related to serum retinol concentration, and height, which was related to vitamin A intake from animal sources, also did not enter the model. All of these variables primarily reflect socioeconomic status. The reason that they did not enter the model may have been because socioeconomic status had already entered in the form of woman's education level.

Home gardening in Central Java can be described as growing vegetables, fruit, or both near as well as away from the house. In general, it does not include keeping poultry, fish, or small animals. Women with a home garden had a higher vitamin A intake in the previous 24 h from plant foods than from animal foods. On the other hand, women with a higher education level had a higher vitamin A intake in the previous 24 h from animal foods than from plant foods, whereas the vitamin A intake from plant foods was not different. The fact that home gardening and socioeconomic status, in the form of woman's education level, entered the logistic regression model that already included vitamin A intake from plant and animal foods in the previous 24 h seemed to indicate that these 2 factors reflected longer-term intake of high–vitamin A plant and animal foods, respectively.

Thus, on the basis of these results, animal foods, fortified foods, or both should be included in food-based programs for improving vitamin A status in areas where economic development allows an increase in their consumption, such as in southeast Asia. However, in areas where it is difficult to increase their consumption, such as in many areas of south Asia, the consumption of fruit and vegetables should be increased and food-preparation methods are needed that can increase the bioavailability of carotene.

In summary, our findings in a survey in Central Java confirmed that plant foods are an important source of vitamin A, but that they contribute less to vitamin A status than had been thought previously when appropriate conversion factors for estimating the vitamin A content of plant foods are used. Therefore, whenever possible, animal foods, fortified foods, or both should be included in food-based programs for improving vitamin A status. In addition, appropriate conversion factors for estimating the vitamin A content of plant food should be assigned when calculating the vitamin A intake. An important and novel relation found among the households of Central Java was that home gardening and socioeconomic status were positively related to serum retinol concentration, which seems to indicate that they reflect longer-term vitamin A intake from plant and animal foods, respectively.

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Review

Dietary carotenoids and their role in combating vitamin A deficiency: a review of the literature

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Objective: To evaluate the evidence that carotene-rich fruits and vegetables can overcome vitamin A deficiency.
Design: Results of studies on the relationship between dietary carotenoids and vitamin A deficiency were evaluated critically.
Results: Increased intake of fruits and vegetables has been shown to be related to improved vitamin A status in many cross-sectional, case-control and community-based studies, but this does not prove causality of the relationship. Many experimental studies indicating a positive effect of fruits and vegetables can be criticized for their poor experimental design while recent experimental studies have found no effect of vegetables on vitamin A status. Thus, it is too early to draw firm conclusions about the role of carotene-rich fruits and vegetables in overcoming vitamin A deficiency. Bioavailability of dietary carotenoids and their conversion to retinol are influenced by the following factors: *S*pecies of carotene; molecular *L*inkage; *A*mount of carotene in a meal; *M*atrix in which the carotenoid is incorporated; *A*bsorption modifiers; *N*utrient status of the host; *G*enetic factors; *H*ost-related factors and *I*nteractions (SLAMANGHI). Studies are required to quantify the impact of these factors, especially of the matrix, host-related factors and absorption modifiers.
Conclusions: The effectiveness of carotene-rich foods in improving vitamin A status and ways of improving carotene bioavailability need further investigation.
Descriptors: food approach, dietary carotenoids, vitamin A, vegetables, fruits

Introduction

Vitamin A supplements and foods fortified with vitamin A can reduce child mortality substantially (Beaton *et al*, 1993). In addition, vitamin A supplements reduce the duration and severity of illness episodes (Ghana VAST Study Team, 1993), increase haemoglobin concentrations when vitamin A deficiency co-exists with anaemia (Bloem *et al*, 1990; Suharno *et al*, 1993), and increase serum and mother's milk retinol levels when given to breast-feeding women shortly after delivery (Stoltzfus *et al*, 1993).

Vitamin A can be obtained from supplements, from fortified foods or from foods naturally rich in vitamin A. Food-based approaches deserve attention because they are more likely to be sustainable in the long run and will increase the intake of other nutrients simultaneously. They are also the most feasible way of providing an adequate dose of vitamin A to women of child-bearing age who should restrict their intake to less than 10 000 IU/day, except during the first month after delivery (WHO/UNICEF/IVACG, 1988).

Retinol-rich foods are most effective in improving vitamin A status. However, except for mother's milk, they are also expensive. Thus yellow and orange fruits and dark green leafy vegetables are often promoted as a means to improve vitamin A status because such foods are rich in provitamin A carotenoids, especially β-carotene. However, the assumption that provitamin A from plant sources can effectively combat vitamin A deficiency has been challenged by results from recent studies (Brown *et al*, 1989; Micozzi *et al*, 1992; Bulux *et al*, 1994; de Pee *et al*, 1995). Therefore, the aim of this paper is to evaluate the evidence that foods rich in provitamin A carotenoids can improve vitamin A status and to examine the factors influencing the bioavailability of dietary carotenoids.

Early studies on vitamin A requirements and carotene absorption

Between 1930 and 1950, a number of studies were performed in Europe to establish vitamin A requirements. This was done by repleting subjects fed a vitamin A-deficient diet and by examining the absorption of carotene from various food sources.

Hume & Krebs (1949) concluded in the so-called 'Sheffield experiment' that 750 μg retinol or 1800 μg purified β-carotene are required to maintain adequate

Appendix 6

Table 1 Interventions with carotene-rich foods and the effect on vitamin A status in vitamin A-depleted populations

Ref.; study site (study)	*Design: description of subjects; treatment*[1]*; fat content of supplement; duration of intervention*	*Results*[2]	*Conclusions and comments; drop-out; control group; sample size*[3]*; control over daily diet during study period*
Roels, Trout & Dujacquier, 1958; Ruanda (Study 1)	Subjects: boys aged 9–16 Treatment: Group 1: 200 g raw grated carrots (19 mg carotene) per day ($n = 5$) Group 2: 200 g raw grated carrots (19 mg carotene) + 18 g olive oil per day ($n = 4$) Group 3: 28 mg carotene + 18 g olive oil per day ($n = 4$) Group 4: 18 g olive oil ($n = 4$) Group 5: placebo ($n = 4$). Supplements were supplied in two meals Fat content of supplement: see above Duration of intervention: 31 days after 8 days on basal diet Other information: 17 subjects had Bitot spots, four subjects did not show signs of xerophthalmia	*Change in serum retinol:* Group 1, 36 → 51 μg/dl Group 2, 32 → 53 μg/dl (n.s.[4]) Group 3, 35 → 56 μg/dl Group 4, 37 → 39 μg/dl (n.s.) Group 5, 33 → 38 μg/dl (n.s.) *Change in serum carotene:* Group 1, 43 → 84 μg/dl Group 2, 48 → 335 μg/dl Group 3, 64 → 501 μg/dl Group 4, 52 → 47 μg/dl (n.s.) Group 5, 49 → 43 μg/dl (n.s.) Changes in serum retinol and carotene levels in Groups 2 and 3 were different from those in other groups ($P < 0.07$ and $P < 0.001$ resp). The range of changes in serum retinol within groups was large (8–46 μg/dl)	After consumption of carrots or purified carotene, both with fat, serum retinol and carotene levels increased. After consumption of carrots without fat the increase in serum retinol was not statistically significant Drop-out: one subject developed diarrhoea Control groups: negative and positive control groups included Sample size: $n < 10$ and responses varied considerably within groups Daily diet: well controlled
Pereira & Begum, 1968; India (Study 2)	Subjects: children aged 2–5, from an orphanage Treatment: 30 g cooked green leafy vegetables (1.5–2.25 mg β-carotene per day) ($n = 29$) Fat content of supplement: no information given Duration of intervention: 3 months Other information: after vegetables an intramuscular injection of vitamin A acetate in oily solution (100 000/200 000/300 000 IU) or placebo was given	*Change in serum retinol:* After vegetable consumption, 22 → 31 μg/dl After intramuscular injection of vitamin A, decrease in all groups, including the placebo group	Increase in serum retinol after consumption of vegetables Drop-out: none Control groups: not included Sample size: $n = 20$–30 Daily diet: controlled Other comments: lack of an effect of intramuscular injection of vitamin A is difficult to explain
Lala & Reddy, 1970; India (Study 3)	Subjects: children aged 2–6 Treatment: Group 1: 40 g amaranth (1.2 mg β-carotene per day) and one chapati ($n = 29$) Group 2: no intervention ($n = 6$) Fat content of supplement: none; daily diet contained 5–7 g fat Duration of intervention: 15 days	*Change in serum retinol:* Group 1: In subjects with initial level <25 μg/dl ($n = 17$), it is increased by 12.6 μg/dl. In subjects with initial level >25 μg/dl ($n = 12$), it increased by 6.2 μg/dl (n.s.) Group 2: no changes	Low serum retinol level increased after consumption of vegetables Drop-out: three subjects, due to respiratory infections Control groups: negative control group was included but it was much smaller than the vegetable group and did not receive any treatment Sample size: Group 1: $n = 20$–30; Group 2: $n < 10$ Daily diet: little information given; different for Groups 1 and 2
Muhilal & Karyadi, 1977; Indonesia (Study 4)	Subjects: children aged 3–5, from 1 village Treatment: village split into two: Group 1: dark green leafy vegetables (1.9 mg β-carotene per day) ($n = 32/39$) Group 2: salt fortified with vitamin A 300 RE/(d) ($n = 43/61$) Serum retinol and β-carotene levels were measured in fewer subjects than haemoglobin. Groups did not differ in nutrient intake and anthropometric parameters Fat content of supplement: no information given Duration of intervention: 75 days	*Change in serum retinol:* Group 1, 20 → 21 μg/dl (n.s.) Group 2, 19 → 23 μg/dl *Change in serum β-carotene:* Group 1, 16 → 32 μg/dl Group 2, 19 → 32 μg/dl *Changes in haemoglobin:* Group 1: no changes ($n = 39$) Group 2, 10.5 → 11.5 g/dl ($n = 61$)	No increase of serum retinol level after consumption of dark green leafy vegetables Drop-out: Group 1 started with 40 and Group 2 with 60 subjects. No information about the smaller number of subjects with retinol than with haemoglobin measurements Control groups: no negative, but positive control group included Sample size: $n = 30$–50 and $n > 50$ Daily diet: recorded for both groups Other comment: increase in serum β-carotene in both groups could be due to consumption of other foods rich in β-carotene, outside control of investigators

Table 1—*(continued)*

Ref.; study site (study)	*Design: description of subjects; treatment[1]; fat content of supplement; duration of intervention*	*Results[2]*	*Conclusions and comments; drop-out; control group; sample size[3]; control over daily diet during study period*
Devadas & Murthy, 1978; India (Study 5)	Subjects: children aged 3–5 Treatment: 1st month 40 g amaranth, 2nd month 8 g leaf protein, 3rd month 1 ml β-carotene solution per day (1.2 mg β-carotene per day in all supplements) ($n = 15$) Fat content of supplement: no information given Duration of intervention: 3 months	Serum retinol level increased from 21 to 29 µg/dl Haemoglobin level increased from 8.4 to 12 g/dl	Increase in serum retinol after consumption of vegetables and purified β-carotene Drop-out: no information given Control groups: not included Sample size: $n = 10–15$ Daily diet: no information given Other comment: it is not possible to separate effects of vegetables from effects of purified β-carotene
Devadas, Premakumari & Subramanian, 1978; India (Study 6)	Subjects: children aged 4–5 Treatment: Groups 1–4: 40–75 g green leafy vegetables (1.2 mg β-carotene per day) ($n = 15$ per group: $n = 5$ for food weighing; $n = 5$ for serum retinol analysis; $n = 5$ for faecal analysis) Group 5: β-carotene in powdered tablet (1.2 mg/d) ($n = 15$, ditto) Group 6: no intervention ($n = 15$, ditto) Groups 1–5 participated in a feeding programme Fat content of supplement: no information given Duration of intervention: 2.5 months	*Change in serum retinol:* Group 1, 14 → 21 µg/dl Group 2, 12 → 20 µg/dl Group 3, 13 → 21 µg/dl Group 4, 13 → 22 µg/dl Group 5, 14 → 22 µg/dl Group 6, 12 → 10 µg/dl (n.s.)	Serum retinol increased as much in the groups that received vegetables as in the group that received purified β-carotene Drop-out: no information given Control groups: negative control group included, but did not participate in the feeding programme Sample size: $n < 10$ for each parameter measured Daily diet: different for Groups 1–5 and Group 6
Jayarajan, Reddy & Mohanram, 1980; India (Study 7)	Subjects: children aged 2–6 Treatment: all groups received 40 g spinach (1.2 mg β-carotene per day), 50 g cooked rice, and: Group 1: no oil ($n = 26$) Group 2: 5 g groundnut oil ($n = 22$) Group 3: 10 g groundnut oil ($n = 22$) Fat content of supplement: see above Duration of intervention 4 weeks Other information: serum retinol also measured until 6 weeks after the end of the intervention	*Change in serum retinol:* Group 1, 20 → 24 µg/dl Group 2, 21 → 29 µg/dl Group 3, 21 → 29 µg/dl It increased most in subjects with an initial level < 20 µg/dl Serum retinol was maintained up to 6 weeks after supplementation	Increase in serum retinol after 40 g spinach daily. Increases were greater when 5–10 g oil was added Drop-out: none Control groups: not included for effect of vegetables, only for effect of oil Sample size: $n = 20–30$ Daily diet: little information given Other comment: it is surprising that the increase in serum retinol was maintained for at least 6 weeks after supplementation
Devadas, Saroja & Murthy, 1980, India (Study 8)	Subjects: children aged 3–5 Treatment: 1st month basic diet with virtually no vitamin A for all subjects, then 2 months: Group 1: basic diet ($n = 5$) Group 2: 142 g papaya (1.2 mg β-carotene daily) ($n = 8$) Group 3: 30 g amaranth (1.2 mg β-carotene daily) ($n = 5$) Group 4: vitamin A (300 RE/d) ($n = 10$) Fat content of supplement; no information given; daily diet contained 5–7 g fat Duration of intervention: 2 months	*Change in serum retinol:* Group 1, 13 → 13 µg/dl (n.s.) Group 2, 13 → 29 µg/dl Group 3, 14 → 29 µg/dl Group 4, 13 → 35 µg/dl *Change in haemoglobin level:* Group 1, 9.2 → 9.8 g/dl (n.s.) Group 2, 9.2 → 10.9 g/dl Group 3, 8.0 → 10.2 g/dl Group 4, 8.9 → 10.8 g/dl	Serum retinol increased as much after consumption of papaya as after consumption of amaranth and it increased most after vitamin A Drop-out: each group started with 10 subjects, no information about 30% drop out Control groups: a negative and a positive control group included Sample size: $n < 10$ Daily diet: controlled

Table 1—(*continued*)

Ref.; study site (study)	*Design: description of subjects; treatment*[1]*; fat content of supplement; duration of intervention*	*Results*[2]	*Conclusions and comments; drop-out; control group; sample size*[3]*; control over daily diet during study period*
Charoenkiatkul, Valyaseri & Tontisirin, 1986; Thailand (Study 9)	Subjects: children of pre-school age who had been in an orphanage >6 months, where they were given vitamin supplements Treatment: Group 1: in wet season, 2 weeks no intervention, 2 weeks cooked ivy gourd (1.1 mg β-carotene per day ($n = 15$) Group 2: in cool, dry season, 2 weeks cooked ivy gourd (1.2 mg β-carotene per day), 2 weeks vitamin supplement (450 RE/day) ($n = 15$) Fat content of supplement: ivy gourd supplement contained 0.2–0.4 g fat per portion Duration of intervention: 2 weeks per treatment	*Change in serum retinol and β-carotene:* Group 1: 2 weeks without intervention: serum retinol and β-carotene decreased from 39 to 25 μg/dl and from 44 to 27 μg/dl, respectively; 2 weeks vegetables: serum retinol increased from 25 to 49 μg/dl and β-carotene from 27 to 106 μg/dl Group 2: 2 weeks vegetables: initial serum retinol level of 35 μg/dl unchanged, serum β-carotene increased from 36 to 87 μg/dl; 2 weeks supplements: serum retinol increased from 35 to 48 μg/dl and β-carotene decreased from 87 to 57 μg/dl Haematocrit remained the same throughout the study period in both groups	The authors ascribe the decrease in serum retinol levels in Group 1 and the lack of increase in Group 2 during first two weeks to discontinuation of vitamin supplements. They conclude that 50 g of vegetables can maintain vitamin A status Drop-out: none Control groups: not included Sample size: $n = 10$–15 Daily diet: controlled Other comment: increases of serum retinol occurred very rapidly and to very high levels
Mariath, Lima & Santos, 1989; Brazil (Study 10)	Subjects: children aged 3–12 Treatment: one buriti sweet from a palm tree daily (0.8 mg β-carotene per day) ($n = 44$); 'take home treatment' Fat content of supplement: 1 g per sweet Duration of intervention: 20 days	Of the 12 subjects with xerophthalmia, 10 improved Of the 32 subjects without xerophthalmia, six of whom had increased RDR at baseline, RDR was normal at follow-up	Vitamin A status improved after consumption of buriti sweet Drop-out: no information Control groups: not included Sample size: $n = 30$–50 Daily diet: no information Other comments: No data about amount of sweets given or about compliance with 'take home treatment' Serum retinol levels were not reported, although they are available from the RDR measurement
Hussein & El-Tohamy, 1989; Egypt (Study 11)	Subjects: boys aged 6–13 Treatment: Group 1: megadoxe vitamin A (200 000 IU) ($n = 7$) Group 2: spinach (3.7 mg β-carotene per day) ($n = 4$), with 10 g oil Group 3: grated carrots (2.4 mg β-carotene per day) ($n = 2$), no information about fat content Fat content of supplement: see above Duration of intervention: 40 days (21 servings in Groups 2 and 3)	*Change in serum retinol:* in all three groups from *c.* 17 to *c.* 34 μg/dl *Change in serum carotene:* Group 1, with 17% Group 2, with 42% Group 3, remained unchanged	Serum retinol increased as much after 21 servings of spinach and carrots as after a megadose of vitamin A Drop-out: none Control groups: no negative, but positive control group included Sample size: $n < 10$ Daily diet: no information Other comment: it is unclear why serum β-carotene increased in the spinach group and in the group given a megadose of vitamin A, but remained the same in the carrot group
Hussein & El-Tohamy, 1990; Egypt (Study 12)	Subjects: boys aged 11–13 Treatment subjects were provided with different amounts of carrots, carrot juice and cooked spinach leaves ($n = 17$) Fat content of supplements: no information given; daily diet provided 35–50 g fat Duration of intervention: 2 weeks	*Change in serum retinol and carotene:* Carrots: 150 g/day resulted in an increase of serum retinol, but 30, 50 or 75 g/d did not Serum carotene levels remained unchanged at all dosages Carrot juice: 30 or 45 ml/day did not change serum retinol or carotene levels Spinach: 150 or 280 g/day increased serum carotene but not serum retinol	An increase in serum carotene was not always accompanied by an increase of serum retinol, nor did the opposite occur Drop-out: none Control groups: not included Sample size: $n = 16$–20 Daily diet: poorly controlled Other comment: it is not clear what amounts of which supplements were given to whom and for how many days

Table 1—(*continued*)

Ref.; study site (study)	*Design: description of subjects; treatment*[1]*; fat content of supplement; duration of intervention*	*Results*[2]	*Conclusions and comments; drop-out; control group; sample size*[3]*; control over daily diet during study period*
Jalal, 1991 Indonesia (Study 13)	Subjects: children aged 2–7 Treatment: red sweet potato and dark green leafy vegetables (5.1 mg β-carotene per day) (vegetables *vs* foods with low carotene content) and/or deworming (*vs* placebo) and/or 25 g coconut fat (*vs* low fat): Group 1: placebo ($n = 40$) Group 2: fat + deworming ($n = 39$) Group 3: vegetables ($n = 39$) Group 4: vegetables + fat + deworming ($n = 40$) Group 5: vegetables + fat ($n = 41$) Group 6: vegetables + deworming ($n = 43$) Fat content of supplement: see above Duration of intervention: 24 days	*Average initial serum retinol* level was 17 µg/dl, and 14 µg/dl for subjects with initial level <20 µg/dl ($n = 165$). Change in concentrations (in µg/dl; average and <20 µg/dl respectively): Group 1, 1.0 (n.s.) and 3.3 Group 2, 5.0 and 8.6 Group 3, 6.3 and 7.6 Group 4, 9.9 and 13.0 Group 5, 10.4 and 10.5 Group 6, 8.3 and 9.1 In highly infected children, combining vegetables with deworming increased serum retinol more than vegetables alone	Increase in serum retinol after consumption of carotene-rich foods and after deworming in combination with fat supplementation. The main source of vitamin A in the supplements was red sweet potato (personal communication) Drop-out: 3.6% Control groups: negative control group included Sample size: $n = 30–50$ Daily diet: about two-thirds of the daily diet was provided by the study
Bulux *et al* 1994; Guatemala (Study 14)	Subjects: children aged 7–12 Treatment: Group 1; placebo (capsule) ($n = 17$) Group 2: retinyl palmitate (1000 RE/day, orally by syringe) ($n = 17$) Group 3: 50 g carrots (6 mg β-carotene per day) with 10 g fat ($n = 17$) Group 4: β-carotene supplement (6 mg/per day ($n = 16$) Fat content of supplement: see above Duration of intervention: 20 days	Serum retinol remained the same in all four groups (34 µg/dl) Serum β-carotene increased almost 3-fold in Group 4. It remained unchanged (13 µg/dl) in the other three groups	The already normal serum retinol level did not increase after consumption of retinol, β-carotene or carrots Consumption of purified β-carotene (6 mg) increased serum β-carotene level, but consumption of carrots did not. Drop-out: 3% Control groups: a negative and a positive control group included Sample size: $n = 16–20$ Daily diet: recorded
Wadhwa *et al*, 1994 India (Study 15)	Subjects: children aged 7–12 from an orphanage Treatment: Group 1: carrots (5 d/week), papaya (2 d/week), coriander-mint chutney (2 d/week) (2.3 mg β-carotene per day for children aged 7–9 and 3.3 mg for those aged 10–12) ($n = 60$) Group 2: radishes (3 µg β-carotene per day) ($n = 54$) Fat content of supplement: no information given; daily diet contained 17 g fat Duration of intervention: 1 month	*Serum retinol level* after the intervention was: Group 1, 25.1 µg/dl Group 2, 15.5 µg/dl	Higher serum retinol level after consumption of carrots, papaya, coriander and mint than after consumption of radishes Drop-out: 5.8% Control groups: negative control group included Sample size: $n > 50$ Diet: recorded Other comment: serum retinol was not determined at baseline
Nasoetion, Riyadi & Baliwati 1994; Indonesia (Study 16)	Subjects: children aged 10–13 Treatment: Group 1: carrot soup (1.8 mg β-carotene per day) ($n = 37$) Group 2: carrot juice (1.8 mg β-carotene per day) ($n = 39$) Group 3: no intervention ($n = 37$) Fat content of supplements: none Duration of intervention: 3 months	*Change in serum retinol:* in subjects with an initial level <30 µg/dl: Group 1, 24 → 28 µg/dl ($n = 18$) Group 2, 25 → 31 µg/dl ($n = 21$) Group 3, 23 → 27 µg/dl ($n = 20$) in subjects with an initial level >30 µg/dl: Group 1, 37 → 35 µg/dl ($n = 19$) Group 2, 38 → 36 µg/dl ($n = 18$) Group 3, 37 → 34 µg/dl ($n = 17$) Changes in serum retinol did not differ between Groups 1, 2 and 3	No increase in serum retinol level after consumption of carrot soup or carrot juice Drop-out: 5.8% Control groups: negative control group included, but this groups was not given any treatment Sample size: $n = 30–50$ Daily diet: no information given

[1] Number of subjects reported is the number used in the data analysis. Data on the number of subjects enrolled in the study can be calculated from the drop-out. Not all authors provide data on the number of subjects enrolled or dropped out, or the reason of drop-out.
[2] Most studies report serum retinol level in µg/dl: therefore this unit is used in the table. In some of the later studies, serum retinol is reported in µmol/l; these values have been converted to µg/dl (1 µmol/l = 28.6 µg/dl).
[3] For evaluating the size of the study, sample size was classified into the following categories: $n < 10$, 10–15, 16–20, 20–30, 30–50, >50.
[4] n.s.: not significant ($P > 0.05$). All changes reported without comment were statistically significant.

vitamin A levels. These requirements were supported in the extensive review on vitamin A by Rodriguez & Irwin (1972) and confirmed in a repletion study by Sauberlich *et al* (1974) who concluded that 1200 µg retinol or 2400 µg β-carotene are required to maintain serum retinol concentrations above 30 µg/dl. Current recommended daily allowances (RDAs) for retinol range from 350 µg for infants to 850 µg for lactating women. The RDA for vitamin A in terms of β-carotene intake depends on the amount consumed in each meal (FAO/WHO, 1988); on average, it is 2100 µg for infants and 5100 µg for lactating women.

The bioavailability of carotene from various foods has been studied by looking at their effectiveness in restoring dark adaptation or maintaining serum levels of retinol and carotene. Carotene from peas and spinach has been found to restore dark adaptation as effectively or even better than carotene in oil (Booher & Callison, 1939; Callison & Orent-Keiles, 1947), while carotene from carrots appears to be less effective than carotene in oil (Callison & Orent-Keiles, 1947). The method of preparation is important: cooked carrots were found to be as effective as blanched carrots (Callison & Orent-Keiles, 1947), while grated raw carrots increased serum carotene levels but cooked carrots did not (van Zeben, 1946). Leitner, Moore & Sharman (1964) found that serum levels of retinol and carotene could be increased by feeding large amounts of carrots and spinach containing 17 mg carotene per day for 3 months.

Other studies have compared the bioavailability of β-carotene from various sources by studying apparent absorption which is calculated by subtracting the amount of carotene in faeces from the amount consumed and dividing the difference by the amount consumed. Between 1935 and 1950, a number of such studies were undertaken in Europe, mainly in adults, while between 1960 and 1980, there were a number of studies in Ruanda, India and Indonesia, mainly in children. Many of these studies have been reviewed by Hume & Krebs (1949) and by Rodriguez & Irwin (1972). Some of the studies listed in Table 1 also measured apparent absorption. In summary, apparent absorption of carotene dissolved in oil ranged from 30 to 99%; from cooked carrots, 1 to 60%; from raw carrots without fat, 1 to 20%; from raw carrots with fat, 25 to 50%; from vegetables with or without fat, 5 to 77%; and from papaya, 46 to 77%. James & Hollinger (1954) reported that the apparent absorption of carotene from sweet potato was 46%. The apparent absorption of total carotene and β-carotene from different sources as measured by Nageswaro Rao & Narasinga Rao (1970) (carrots, 36% and 81%; dark green leafy vegetables, 58% and 76%; and papaya, 46% and 90%, respectively) gives the impression that absorption of β-carotene may be greater than that of total carotene. All of these studies were carried out with a small number of subjects and absorption varied widely among individuals in the same study.

Absorption is underestimated when carotene extraction from the diet is incomplete, or when no correction is made for the amount of carotene excreted in faeces when the basal diet is being consumed. However, carotene absorption is more likely to be overestimated. This can happen when carotene extraction from faeces is incomplete. It can also happen if the assumption that carotenoid absorption is represented by the total amount of carotenoids not found in the faeces is incorrect, which is probably the case. In two studies investigating the absorption of β-carotene and retinol using ^{14}C-labelled compounds (Goodman *et al*, 1966; Blomstrand & Werner, 1967), 8–17% of ingested β-carotene and 7–41% of ingested retinol was recovered in the lymph. This suggests that a considerable proportion of β-carotene and retinol is metabolized in the gut and is not available for absorption. Thus, studies on apparent absorption almost certainly overestimate real absorption.

We conclude, as did the Expert Groups of FAO/WHO (1967, 1988) and Rodriguez & Irwin (1972), that data on the absorption of dietary carotenoids are too scanty and too variable to predict their bioavailability accurately. One of the causes of variability is the large number of factors that influence the bioavailability of dietary carotenoids, as discussed below.

At the same time that the studies on requirements and absorption were being conducted in Europe, Bloch (1924) reported from Denmark that cases of xerophthalmia appeared when consumers changed from butter to margarine. Hardly any new cases of xerophthalmia were reported once margarine was fortified with vitamin A. Since then, margarine and fat spreads in Europe have been fortified with vitamin A and only few further studies on vitamin A deficiency have been carried out in Europe because the condition has become so rare. Contrary to what may be expected, vegetarians in Europe do not seem to be at high risk of developing vitamin A deficiency as is illustrated by a study in France which found no difference in serum retinol concentrations between vegetarians and non-vegetarians (Millet *et al*, 1989). This seems to be due to the relatively large amount of retinol in the diet of the vegetarians (300–500 RE/day, in addition to the 1200–1400 RE derived from β-carotene). In developing countries, however, where foods naturally rich in retinol are scarce and often beyond the reach of most people and where foods are rarely fortified with retinol, studies into the effectiveness of dietary carotenoids to reduce vitamin A deficiency have continued.

Cross-sectional, case-control and community-based intervention studies in vitamin A-depleted populations

In developing countries few cross-sectional studies have been carried out on the relation between vitamin A status and vitamin A intake. In Senegal, a correlation was found between serum concentrations of retinol and carotene (Rankins *et al*, 1993). This may reflect a concurrent intake of carotene-rich and retinol-rich foods or it may be that carotene-rich foods increase serum levels of both carotene and retinol. Morris *et al* (1993) found no significant association between the increase in serum retinol and the consumption of mangoes and red palm oil, while the increase in serum retinol was associated with the consumption of dried leaves.

Many case-control studies have been devoted to the relationship between diet and vitamin A deficiency. One of the earliest studies was reported from Indonesia by Blankhart (1967). Children aged 2–5 consumed very little retinol, while consumption of β-carotene supplied one-third of the recommended vitamin A intake in healthy children and one-fifth in malnourished children some of whom were night-blind. Protein and energy consumption levels in the groups were comparable. Another case-control study in Indonesia found that controls consumed mother's milk, eggs, fish, dark green leafy vegetables, carrots, and carotene-containing fruits more frequently than did children with corneal xerophthalmia (Tarwotjo *et al*, 1982). Pepping *et al* (1989) observed in Tanzania that controls consumed green leaves, whole milk and butter more frequently than did cases. A study in Aceh, Indonesia, used logistic regression to examine the relationship of various factors with xerophthalmia. It was found that the consumption of dark green leafy vegetables, yellow fruits and eggs was inversely related to the risk of xerophthalmia (Mele *et al*, 1991). Breast-feeding was not included in the model and odds ratios were calculated from data on the group that never consumed a particular food and from the group that consumed the food at least once per month. When analyses are performed in such a way, it is not surprising that consumption of common foods is found to be inversely related to xerophthalmia. Within a large vitamin A supplementation trial in Sudan, food consumption was also investigated (Fawzi *et al*, 1993, 1994). Although the supplement did not have an impact on the incidence of xerophthalmia or mortality, dietary intake of vitamin A and of carotene were both strongly and inversely associated with risk of xerophthalmia and mortality. Retinol intake was inversely asociated with the incidence of xerophthalmia but not with mortality. Relative risks were calculated by comparing children in the lowest quintile, who often consumed no retinol or carotene, with those in the highest quintile.

Other studies suggest a stronger protective role of breast milk and other sources of retinol than of carotene-rich foods. Stanton *et al* (1986) found that lower consumption levels for both milk and eggs were related to a greater risk of xerophthalmia, but they did not find an increased risk for a lower consumption of vegetables and fruits. Keith West and colleagues reported a protective role of breast feeding against xerophthalmia in early childhood. Cases tended to consume papaya, mango, eggs and fresh small fish less frequently than did controls, while the frequency of consumption of fresh green leaves was comparable in both groups (West *et al*, 1986).

Some criticisms can be directed towards case-control studies. They do not test causality. It is not possible to determine whether or not the difference between cases and controls is indeed the cause of disease in the cases; it could also be possible that the difference arose after the subjects became cases. In addition, it is difficult to mask interviewers completely with respect to the status of a subject because children with xerophthalmia cannot hide their affected eyes. If the interviewer is aware of the hypothesis, this will make it more difficult to obtain objective answers about food consumption. Therefore, although case-control studies are very useful for generating hypotheses, experimental studies are necessary to test them.

Community-based interventions which promote cultivation and/or consumption of vitamin A-rich foods should first of all lead to increased consumption of carotene-rich foods. A number of community-based interventions, and one intervention based in a nutrition rehabilitation centre (Venkataswamy *et al*, 1976), have been evaluated for their impact both on the consumption of carotene-rich foods and on vitamin A status. In Tamil Nadu in India, papaya and drumstick leaves were provided in conjunction with nutrition education. It was reported that after one year, the β-carotene content of the diets had improved and serum retinol levels in children had increased (Chandrasekhar & George, 1993). Other evaluations reported a reduction of the prevalence of night blindness or xerophthalmia after providing meals and nutrition education (Venkataswamy *et al*, 1976; Devadas & Premakumari, 1993), introduction of a leaf concentrate (Rose, 1993), nutrition education combined with home garden promotion (Ngu *et al*, 1994), or promotion of green leaves through mass media (Islam, 1993). The abstracts of five of the studies, presented at the XVth (1993) or the XVIth (1994) IVACG Meeting, do not provide enough detail to carefully evaluate the results. Evaluation of a large home gardening programme in Bangladesh found an increase in vegetable and energy consumption, an increase in household income, and a small reduction of the prevalence of night blindness (HKI/AVRDC, 1993; Talukder *et al*, 1994). Evaluation of a large social marketing programme of ivy gourd in Thailand also revealed increased production and consumption, while no clear impact on vitamin A status was found (Smitasiri *et al*, 1993). It was concluded that the programmes, despite the lack of an effect on vitamin A status, were successful in many other aspects.

In the evaluation of the community-based programmes, only that of the Bangladesh programme (HKI/AVRDC, 1993) compared the changes in the intervention community with changes in a control group. Thus it is difficult to draw conclusions from the other studies. We realize that it is not easy to define an appropriate control group because it is difficult to determine the exact boundaries between communities that are influenced by a programme and those that are not. If control communities are chosen far away from the intervention communities, other factors could also lead to a difference. Ideally, carefully controlled experiments should be done to select foods that can improve vitamin A status. These could then be followed by properly evaluated community interventions which look at changes of both intake and status.

Intervention studies with dietary carotenoids in vitamin A-depleted populations

The designs and results of intervention studies with carotene-rich foods in vitamin A-depleted populations (Table 1) are discussed below.

Study sites and subjects

All studies were carried out in regions with a high prevalence of vitamin A deficiency and all of them were done with children, mostly of pre-school age. Sometimes the children were poorly nourished (Studies 5, 6 and 8), but it is not known to what extent nutritional status could have influenced the response to dietary carotenoids. If the intake of vegetables was increased without correcting deficiencies other than vitamin A, the full potential of dietary carotenoids would not have been achieved. On the other hand, if nutritional status with respect to other nutrients was also improved, the bioavailability of retinol and bioavailability/

bioconversion of dietary carotenoids would also be increased.

Inclusion of control groups
Studies should include both negative and positive control groups. Many studies did not include a negative control group to check whether vitamin A status of the subjects would also have changed without an intervention. A change in vitamin A status of a negative control group can be due to changes in the diet, which can occur in any study group, and/or to regression to the mean when subjects are selected on the basis of low or high vitamin A status (Davis, 1976). Five studies included a negative control group in which the subjects were given some type of placebo (Studies 1, 8, 13–15). The design of Study 13 was very elegant: all treatment groups received similar foods which only differed in vitamin A content. The negative control group showed a smaller improvement of vitamin A status than the groups given red sweet potato and dark green leafy vegetables, but the increase of 3.3 μg/dl for subjects with initial levels <20 μg/dl was significant. This emphasizes the need for a negative control group. Study 15 used a similar design but, because vitamin A status was only measured after the intervention, it could not be concluded, although it was stated that subjects were randomly allocated to the groups, whether the difference between the groups was indeed due to the intervention or already existed before the intervention.

Three studies included a negative control group which was not given any treatment (Studies 3, 6 and 16). In two of these studies there was a large difference in intake of total energy and fat between the treatment groups and the control group (Studies 3 and 6). This could have led to erroneous conclusions because adding fat to vegetables can increase vitamin A status much more than vegetables alone (Studies 7 and 13). In the third study (Study 16) the energy given to the carrot groups was minimal and thus no large difference was created with the negative control group.

Five studies (Studies 1, 4, 8, 11 and 14) included a positive control group. This allowed a comparison with the effect of a similar amount of vitamin A given as retinol (Study 8), carotene (Study 1), β-carotene (Study 14), salt fortified with retinol (Study 4), or a megadose of vitamin A (Study 11).

In Study 9, subjects were their own control but they did not have stable baseline serum retinol levels because their routine vitamin supplements were withheld just before the study. Subjects should also be randomly allocated to the treatment groups, which did not happen in all studies (Studies 3, 4 and 6).

Sample size and drop-out
It is important that the group size is adequate, as determined by power calculation, and that the numbers of subjects in the groups are approximately equal. In the studies examined, the numbers of subjects per group varied greatly between 15 and 60 but in some studies very few subjects were involved (Studies 1, 6, 8 and 11) or the numbers of subjects per group differed strongly (Study 3). The variation in response within the groups with very few subjects was often large (Study 1).

When relatively many subjects do not complete a study, the results can be confounded especially when the drop-out is related to the study or its outcome parameters. As many reports did not give details about drop-out or the number of subjects initially enrolled, this could mean that all subjects completed the study. This is possible when the study was conducted in an institution, such as an orphanage, or it could mean that the authors have only reported results of those subjects who completed the study. Two of the studies reported a relatively large drop-out. Study 4 reported results on only 75% of subjects for serum levels of retinol and carotene, but on 100% of subjects for haemoglobin. This difference may have been due to problems in obtaining enough serum or to problems with the analysis of retinol in serum. In either case, the drop-out would not have confounded the conclusions because it was not selective. For Study 8, no reason was given for the relatively high rate of drop-out in some of the groups. Therefore, selective exclusion of subjects cannot be excluded.

Duration of intervention
Carotene-rich foods were consumed over a period lasting from two weeks to three months. It is important that studies are carried out for a sufficient length of time. For example, with respect to changes in haemoglobin levels, no changes were seen when vegetables were consumed for a short period of time (<14 days; Study 9), but increased haemoglobin levels were reported when vegetables were consumed for more than 60 days (Studies 4, 5 and 8). Other studies have shown that vitamin A supplementation of anaemic subjects with a marginal vitamin A status can result in an increased haemoglobin level (Bloem *et al*, 1990; Suharno *et al*, 1993).

Avoiding unwanted differences in diet among groups
Designing a food intervention study is very difficult because it is essential that only the dietary component of interest differs among the groups being studied. Because vitamin A-rich foods cannot be exchanged readily for foods with virtually no vitamin A without subjects noticing any difference, food interventions can generally not be carried out with a completely masked study design. With an unmasked study design, complete randomization of treatment could lead to undesirable changes in food consumption in the control group since participants will realize that the other group is receiving a different treatment. A change in food consumption could counterbalance any effect of the supplement, because often the supplement is small in relation to the daily diet.

Because allocation to treatment group and daily diet during the study are so critical, studies should report how subjects were allocated to treatment groups and whether their daily diet remained unchanged. Most reports do not give such information or only give information about daily diet but not about changes (Studies 4, 8, 13 and 14).

When the total daily diet can be provided in an institution such as an orphanage (Studies 2, 9 and 15), control of the total diet and of other factors should be reasonable. However, recent arrivals in an orphanage are likely to be offered more protein and energy which could also increase vitamin A status independent of a specific effect of vegetables. In Studies 2 and 15, information was not provided on how long the children had been in the orphanage before the study began. Another way to maximize control over the daily diet is by providing a large proportion of the diet. For example, Jalal (Study 13) provided children with one meal and two snacks each day.

Amount of carotene and types of foods provided
In the studies reported, daily β-carotene intake was between 1.2 mg and 12.7 mg. Generally this came from dark green leafy vegetables (Studies 2–4, 6–9, 11 and 12) but carrots (Studies 1, 11, 12, 14 and 16), papaya (Study 8), a sweet made from a palm fruit (Study 10) and a combination of vitamin A-rich foods (Studies 5, 13 and 15) were also provided. In some studies, fat was supplied with the vegetable supplement while in other studies, no information on fat content of the diet was supplied. Only in one of the studies with carrots (Study 14) was fat (10 g) provided with the carrots. However, in most studies, except for Study 16, vegetable supplements appears to have been provided as part of a meal containing at least some fat.

A daily intake of 1.2 mg dietary β-carotene, equivalent to 200 retinol equivalents (RE), is rather low. If the results of Sauberlich *et al* (1974) are used to calculate the requirement of dietary β-carotene, accounting for the finding that the bioavailability of β-carotene dissolved in oil is three times greater than for β-carotene from vegetables and fruits, 0.9-1.8 mg β-carotene (150–300 RE) would be needed to assure adequate dark adaptation levels and 3.6 mg (600 RE) to maintain serum retinol concentrations above 20 μg/dl. The RDA set by the FAO/WHO (1988) is 400 RE for children 1–10 years old, 500 RE for children 10–12 years old, and 600 RE for children 12–15 years old. Perhaps subjects who were given 1.2 mg dietary β-carotene in any of the studies obtained some vitamin A from other sources, but that might have been difficult for participants from orphanages. The vitamin A status of the subjects studied by Sauberlich *et al* (1974) and by Hume & Krebs (1949) were depleted prior to studying their requirements, while vitamin A stores of the subjects of the studies summarized were marginal. It is not likely that the subjects observed in these studies were more capable of using dietary and purified β-carotene than the subjects studied by Hume & Krebs and by Sauberlich *et al*. Therefore, it remains unclear why some of the studies found an increase in serum retinol levels when feeding vegetables which contained only 1.2 mg β-carotene, while according to the recommendations they would have needed at least two to three times more.

Magnitude of change of vitamin A status
In most studies subjects had relatively low serum retinol levels. Some studies found no increase of serum retinol levels (Studies 6, 16 and 18), while others reported increases ranging from 3 to 24 μg/dl. It is however often difficult to evaluate the magnitude of the increases due to weaknesses of design such as the lack of a negative control group. More than half of the studies tested whether the increases in treatment groups were significant by comparing the value of the whole group at baseline with the value of the whole group at follow-up (Studies 2, 4, 5, 7, 9, 14 and 15). Other studies calculated the change at the individual level and tested whether the mean change of the group was different from 0 (Studies 3, 6, 8, 11–13 and 16). Because the variation of a change is smaller than the variation of baseline and follow-up values at a group level, such paired testing is more likely to detect changes. Other advantages of paired testing are that changes can be related, for example, to baseline levels while controlling for the influence of other factors such as weight change (analysis of covariance).

Evaluation of the effect of dietary carotenoids
Many studies had perhaps the best study design possible under the prevailing circumstances, such as limited funds, and it is only through studies that have been conducted that the importance of certain aspects of design, such as adequate control groups, can be established. However, when evaluated critically, we have to conclude that the design of most of the studies was poor. Three of the studies (Studies 4, 14 and 16) did not support the hypothesis that carotene-rich vegetables and fruits can improve vitamin A status, while the other 13 studies (Studies 1–3, 5–13 and 15) supported the hypothesis. Only half of the studies (Studies 1, 3, 6, 8 and 13–16) fulfilled one of the most important criteria of an intervention study, namely inclusion of a negative control group. Six of those studies however suffered from other weaknesses in study design: the control group was very small (Study 3); the control group did not receive any treatment (Studies 6 and 16); no explanation was provided for the high rate of drop-out (Study 8); baseline values were not available (Study 15); or the variation in response within treatment groups was very large and the number of subjects was very small (Study 1). The two remaining studies which included a negative control group suffered less from weaknesses in design. The study by Bulux *et al* (Study 14) was conducted with vitamin A-replete subjects. Therefore no effect was found on vitamin A status; an effect on serum carotene levels, which was found after supplementation with purified β-carotene, was not found after feeding carrots with fat. Jalal (Study 13) reported an increase of serum retinol, which was mainly attributed to the consumption of red sweet potato, rather than of vegetables (personal communication). It may well be that the bioavailability of β-carotene from red sweet potato is better than that from vegetables because of the nature of the matrix (see below).

Three studies not included in Table 1 reported that red palm oil, which is very rich in carotenoids, has a positive impact on vitamin A status. The studies suffered from weaknesses in design, but two of them (Roels *et al*, 1963; Lian *et al*, 1967) included a negative control group in which serum retinol levels did not change. In the other study (Rukmini 1994) changes were almost the same as in the positive control group which received retinol. An ecological study reported a negative correlation between consumption of red palm oil and occurrence of vitamin A deficiency (Le Francois *et al*, 1980). This supports the suggestion that red palm oil improves vitamin A status. The improvements of vitamin A status of the subjects given a buriti sweet (Study 10) could indeed be attributable to the buriti sweet because the matrix in which the β-carotene is found is more favourable in the fruit than in leafy vegetables and its composition is comparable to red palm oil. However, the poor design of that study does not allow firm conclusions.

In conclusion, there is no good reason to doubt the effectiveness of red palm oil in improving vitamin A status. It might be that yellow and red sweet potato can improve vitamin A status, but the assumption that carotene-rich vegetables and fruits can improve vitamin A status is based on results of studies with poor designs. However, well designed studies which argue against this assumption are scarce too. Therefore, there is an urgent need for studies with good designs to test which carotene-rich vegetables and fruits can combat vitamin A deficiency.

Recent studies in vitamin A replete populations

In recent years, interest in the bioavailability of β-carotene from fruit and vegetables in vitamin A replete populations has grown because the incidence of cancer and of coronary heart disease has been found to be negatively correlated with the consumption of fruit and vegetables (Byers & Perry, 1992; Manson *et al*, 1993). This correlation has been attributed in part to the antioxidant properties of β-carotene. Some groups have conducted intervention studies to examine whether an increased consumption of vegetables and/or fruits has an effect on serum β-carotene levels.

Consumption of carrot juice containing 20 mg β-carotene, 10 mg α-carotene and 10 mg other carotenoids daily for 7 or 14 days increased serum levels of α- and β-carotene (Kim, Simpson & Gerber, 1988). In another study, the serum β-carotene levels reached their peak 5 h after consumption of carrots containing 8 mg β-carotene (Jensen *et al*, 1986). Brown *et al* (1989) provided meals containing fat providing 40% of total energy with foods naturally rich in β-carotene or containing synthetic β-carotene in a cross-over design. Group 1 received 30 mg synthetic β-carotene or 29 mg dietary β-carotene in carrots. Group 2 received 12 mg synthetic β-carotene or 6 mg dietary β-carotene in broccoli or tomato juice without β-carotene. Serum β-carotene levels were monitored for 11 days after the meal. In Group 1 the increase after the carrot meal was only 14% of that after synthetic β-carotene. In Group 2 serum β-carotene levels increased only after synthetic β-carotene. Micozzi *et al* (1992) gave the same foods for a period of 6 weeks and observed similar effects. In another study, the maximum increase after consumption of 6 mg dietary β-carotene in cooked carrots for 7 days was only 9% of the maximum increase after synthetic β-carotene (Masaki *et al*, 1993). No information was provided on the fat content of the meals. It can be concluded that the relative bioavailability of β-carotene from carrots compared with that of β-carotene in oil (9–18%) is less than the factor of one third which is generally used (FAO/WHO, 1988).

Many groups also observed large (3- to 4-fold) inter-individual variation in the serum β-carotene response to either dietary carotenoids (Brown *et al*, 1989; Bowen *et al*, 1993; Carughi & Hooper, 1994) or purified β-carotene (Dimitrov *et al*, 1988). This wide range is remarkable and could perhaps be attributable to genetic factors.

Most of the intervention studies in vitamin A replete populations have used carrots as the dietary source of β-carotene. This is understandable because their carotene content is high and they can be prepared in many different ways. However, it is also necessary to use other foods such as dark-green leafy vegetables and fruits, because it is expected that those foods may give different responses because of their differences in matrix characteristics.

Recent studies in Indonesia

In 1992, we conducted a cross-sectional study in Bogor District, West Java, Indonesia, to investigate the vitamin A intake and status of breast-feeding women ($n = 73$). Their vitamin A intake was estimated to be 2900 RE per day, of which 450 RE was of animal origin. Despite the fact that the vitamin A intake was well above the RDA for this group of women (850 RE), 30% of the women had serum retinol levels regarded as marginal (< 20 µg/dl). The intakes were estimated by food composition tables available in Indonesia but we have shown recently that these tables generally over-estimate the provitamin A content of foods by a factor of two (West & Poortvliet, 1993). In addition, we have found that the food frequency questionnaire used to assess vitamin A intake over-estimated food consumption (de Pee *et al*, submitted for publication). Even so, intakes of provitamin A in the women should have been sufficient to maintain adequate serum vitamin A levels. Furthermore, serum retinol levels were found not to be related to provitamin A intake but weakly related to retinol intake, although the intake of retinol was less than 20% of that of provitamin A. Because this suggested that the bioavailability of carotenoids from food was lower than generally assumed we decided to conduct an intervention study in the same area to examine the effectiveness of vegetables in improving vitamin A status (de Pee *et al*, 1995).

Women ($n = 191$) breast-feeding a child aged 3–17 months, with a haemoglobin level < 130 g/l and haematocrit < 0.38 were enrolled in a 12-week intervention. One group received vegetables stir-fried according to local custom. To examine the effect of a similar amount of β-carotene in a simpler matrix, a second group received a wafer enriched with β-carotene, iron, vitamin C and folic acid. A third group received a non-enriched wafer to control for effects of additional energy intake. The amounts as analysed for the cooked vegetable supplement and for the enriched wafer was for β-carotene 3.5 and 3.5 mg, for iron 5.2 and 4.8 mg, and for fat 7.8 and 4.5 g, respectively. Assignment to vegetable or wafer groups was done by village. Wafers were distributed double-masked.

In the enriched wafer group, there was an increase compared with baseline (mean (95% CI)) in serum retinol (0.32 (0.23; 0.40) µmol/l), breast-milk retinol (0.59 (0.35; 0.84) µmol/l) and serum β-carotene (0.74 (0.59; 0.89) µmol/l). In the other two groups no changes were found except for a small increase in breast-milk retinol concentration in the non-enriched wafer group (0.16 (0.02; 0.30) µmol/l) and a small increase in serum β-carotene in the vegetable group (0.03 (0.00; 0.06) µmol/l). Changes in iron status were similar in all three groups. It was concluded that an additional daily portion of dark green leafy vegetables did not improve vitamin A status, while an equivalent amount of β-carotene from a simpler matrix produced a marked improvement.

This result is contradictory to the results of many of the studies summarized in Table 1 and needs to be examined critically. The vegetables contained 3.5 mg β-carotene which is 70% of the RDA. The change in vitamin A status in the women who received the enriched wafer was large. Both negative and positive control groups were included in the study. The negative control group received the same amount of additional fat and energy as the other two groups, but did not receive any additional carotenoids. The positive control group received the same amount of energy, fat and β-carotene as the vegetable group but the matrix of the carotenoids was simpler. It had been planned, and was confirmed by observation, that all supplements were consumed and that the usual daily diet of participants did not change due to the intervention. Only 8% of the subjects did not complete the study mainly due to unplanned pregnancies or to moving away from the study area. Results from more than 55 women in each treatment group were available for analyses. The response in serum β-carotene in the enriched wafer group was very large, while there was almost no variation in response in the other two groups. This suggests that the bioavailability of β-carotene in the vegetable portions was poor which may be attributed to the matrix of the leaves.

In our opinion, the study was designed carefully. Since these findings are contradictory to some, but not all, previous results, additional carefully controlled studies are required to test the effectiveness of dark green leafy vegetables in improving vitamin A status. In addition, the various factors involved in carotene bioavailability should be investigated to find ways to improve the bioavailability of carotenoids from different foods.

Factors influencing bioavailability and bioconversion of dietary carotenoids

In addition to knowing the amount of individual carotenoids present in a food (West & Poortvliet, 1993), it is important to know the bioavailability with respect to the person or experimental animal in question. Bioavailability is defined as the proportion of a nutrient ingested which becomes available to the body for metabolic processes (Macrae, Robinson & Sadler, 1993).

The early studies investigating the bioavailability of dietary carotenoids, as summarized above, concluded that purified carotene in oil is more bioavailable than carotene from leafy vegetables and carrots, and that grinding and homogenization of foods increases carotene bioavailability. We have ordered the factors influencing the bioavailability of carotenoids, especially of β-carotene, as the mnemonic 'SLAMANGHI': *S*pecies of carotene; molecular *L*inkage; *A*mount of carotene consumed in a meal; *M*atrix in which the carotenoid is incorporated; *A*bsorption modifiers; *N*utrient status of the host; *G*enetic factors; *H*ost-related factors and *I*nteractions. A quantification of these factors would enable prediction of the bioavailability of carotenoids of certain foods under specified circumstances.

Species of carotenoids
About 50 of the 600 naturally occurring carotenoids have provitamin A activity (Simpson, 1983). The vitamin A activity of β-carotene has been set, on a weight basis, at one-fourth to one-tenth of that of retinol, depending on the amount of β-carotene in a meal, while that of other provitamin A carotenoids has been set at one-twelfth (FAO/WHO, 1988). This is however a gross over-simplification (Underwood, 1984). Several stereo-isomers exist for each carotenoid. All-*trans*-β-carotene has more provitamin A activity than its *cis* isomers (Sweeney & Marsh, 1971), but whether one isomer is absorbed better than the other is not known yet. Cooking can convert all-*trans*-β-carotene to *cis* isomers.

Linkages at molecular level
Some hydroxycarotenoids exist as esters, such as of β-cryptoxanthin in papaya (Khachik *et al*, 1991). These esters need to be hydrolysed prior to absorption but it is not known whether hydroxycarotenoids present as esters are any less bioavailable than their unesterified counterparts.

Amount of carotene
Carotenoids are absorbed through passive diffusion and the proportion absorbed decreases with an increasing amount of carotenoids in a meal. Therefore, the FAO/WHO (1988) guidelines state that the amount of dietary β-carotene equivalent to 1 µg retinol is 4 µg, 6 µg or 10 µg, depending on whether the amount of β-carotene in a meal is <1 mg, 1–4 mg or >4 mg, respectively. There is evidence from animal experiments that some carotenoids inhibit the absorption of other carotenoids (White *et al*, 1993).

Matrix
The matrix in which β-carotene is embedded in a food is a very important determinant of its bioavailability. In green leaves, β-carotene molecules are organized in pigment-protein complexes located in cell chloroplasts. In other vegetables and fruits where β-carotene does not play a role in photosynthesis, it is located in the chromoplasts of cells (Czygan, 1980) where it is often found in lipid droplets but can, depending on the type of chromoplast, also be bound to protein. To free β-carotene from its matrix, cells first need to be disrupted. Further, the chloroplast or chromoplast needs to be accessed, and the β-carotene molecule, if bound, has to be separated from its ligand. Releasing β-carotene from a pigment-protein complex would be more difficult than freeing it from a lipid droplet. It is clear, therefore, that β-carotene in a fat matrix is more bioavailable than β-carotene from vegetables and fruits and that cooking and reduction of particle size, by grinding or homogenization, can reduce matrix effects. However, because thorough destruction of the matrix, for example by extensive cooking, could also destroy the β-carotene molecules (Rahman, Wahed & Ali, 1990), an optimum must be found between maximal destruction of the matrix and minimal destruction of β-carotene.

Absorption modifiers
Because the mucosal cell absorbs β-carotene from lipid micelles (Erdman, Bierer & Gugger, 1993), the diet should contain sufficient fat for efficient micelle formation. It could be that it is important to distinguish certain types of fat (Marmor *et al*, 1994). Other dietary factors, such as fibre, including pectin (Rock & Swendseid, 1992) and cellulose (AVRDC, 1987), chlorophyll

(AVRDC, 1987) and non-provitamin A carotenoids, such as lycopene (AVRDC, 1987) can reduce the bioavailability of β-carotene.

Nutrient status
Absorption of carotenoids is not influenced by carotene status or vitamin A status, because absorption occurs through passive diffusion. Conversion of carotene to retinol, however, is influenced by serum retinol level. An adequate serum retinol level has an inhibitory effect on the enzyme that cleaves carotene into retinol (Villard & Bates, 1986). There is also evidence that by improving an impaired zinc status, vitamin A status can be improved as well (Shrimpton *et al*, 1983). Protein status should be adequate in order to ensure that the metabolism of carotene and retinol is normal.

Genetics
The conversion of β-carotene to retinol is mediated by a cleavage enzyme (Villard & Bates, 1986) and there is evidence that some people have a genetic defect which renders them unable to convert β-carotene to retinol (Blomstrand & Werner, 1967; McLaren & Zekian 1971). Another aspect of carotene bioavailability in which genetic factors may play a role is in the functioning of the gastro-intestinal tract, such as in inherited fat malabsorption, low enzymatic digestion efficiency, or poor synthesis of thyroid hormones, proteolytic enzymes and/or bile salts. The wide range of responses to β-carotene among individuals might also be related to genetic differences. Such differences can be illustrated by differences in carotenoid metabolism among species; as summarized by van Vliet (this issue).

Host-related factors
In addition to genetic factors, there are other host-related factors which can influence carotene bioavailability. We can distinguish factors such as age, as infants might handle carotenoids differently from adults or the elderly, and factors such as gastro-intestinal infections (*Helicobacter pylori*) and parasites (*Giardia lamblia, Ascaris lumbricoides*, hookworm). These infections can cause maldigestion, malabsorption and excessive loss of gut epithelium (Solomons, 1993; Erdman, Bierer & Gugger, 1993).

Interactions
All factors mentioned can also interact with one another to affect carotene bioavailability. For example, the effect of intestinal parasites might be more pronounced when it interacts with the matrix effect of carotenoids in leaves than with the matrix of carotenoids in fat. Reducing the inhibitory effect of one factor may be counteracted by simultaneous enhancement of that of another, such as mentioned above for cooking.

The most important factors in the mnemonic 'SLAMANGHI' in countries with a vitamin A deficiency problem seem to be the matrix, the gastro-intestinal infections referred to under host-related factors, and absorption modifiers such as fat. Research should first of all focus on the magnitude of these three factors and on ways of reducing their negative effect on carotenoid bioavailability.

A similar identification and quantification of factors is necessary for the bioconversion of β-carotene to retinol. This could include factors such as the possible importance of site-specific cleavage (Wang, 1994).

Suggestions for research on the role of carotene-rich foods in combatting vitamin A deficiency

It is clear from what has been discussed until now that there is need for additional intervention studies to be carried out on the effectiveness of carotenoids from vegetables and fruits. In addition, factors that influence bioavailability should be investigated. Operational research should investigate ways of increasing the consumption of effective foods and whether increased intake indeed results in improved status. Criteria for the design of food intervention studies can be identified as follows.

First of all, one should question what carotene-rich foods should be investigated. The bioavailability of carotenoids from dark green leafy vegetables and carrots needs to be studied because we cannot draw firm conclusions from the data available. Red palm oil has been shown to improve vitamin A status, while almost no intervention studies have used fruits. Fruits are expected to contain β-carotene which is reasonably bioavailable because cross-sectional and case-control studies have suggested a positive relationship between the consumption of carotene-rich fruits, such as mango, and vitamin A status (Carlier *et al*, 1992) and β-carotene located in the chromoplasts of fruits is expected to be more bioavailable than β-carotene located in the chloroplasts of dark green leafy vegetables. Studies with roots and tubers are scanty and have mainly focused on yellow and red sweet potato (James & Hollinger, 1954; Jalal, 1991). Because of the cytological characteristics of β-carotene in roots and tubers, carotenoid bioavailability is likely to be comparable to that in fruits.

Some work has been done on developing processed foods. Red sweet potato has been used to make snacks in Indonesia (Jalal, 1991) and flour for gruel and pancakes in Guatemala (Lopez *et al*, 1993). Solar drying devices have been developed to dry vegetables and mangoes in order to extend the period for which they are available (Linehan *et al*, 1994). Vegetable concentrates have been made to reduce bulkiness (Rose, 1993; Rahman *et al*, 1994). The buriti sweet (Mariath, Lima & Santos, 1989) and chicken liver chips (Wasantwisut *et al*, 1994) are examples of processed foods which are not expected to have a large bioavailability problem. Processed and preserved foods should also be tested for their effectiveness in improving vitamin A status.

Intervention studies aimed at investigating the effectiveness of different foods or food groups in improving vitamin A status should be designed very carefully, taking into account the following aspects of design.

Hypothesis and outcome parameters
Studies should be designed to test a clearly defined hypothesis. The hypothesis should relate to a parameter of vitamin A status. Of the many parameters for measuring vitamin A status (Olson, 1992), most intervention studies test hypotheses based on measurements of serum retinol. As an increase in serum carotene level is also expected when carotene-containing foods are consumed, we suggest that serum levels, especially of β-carotene, should also be measured. An additional

reason for such measurements is that they are more sensitive than changes in retinol level which is more closely regulated. Because an increase in vitamin A status can also improve suboptimal iron status (Bloem *et al*, 1990; Suharno *et al*, 1993), iron status parameters could also be considered. However, it should be kept in mind that attempts to test secondary hypotheses should in no way distract from testing the primary hypothesis.

Sample size and drop-out
The hypothesis should state at what level the difference in the change in vitamin A status parameter among the groups is relevant. In addition, the minimum sample size required to test the hypothesis should be established prior to carrying out the study. Information should be provided about the number of subjects dropping out of the study and the reasons for this drop-out, in order to judge whether selective drop-out has confounded the results of the study.

Study population
Bioavailability of dietary carotenoids can be studied in vitamin A replete populations by measuring changes in serum carotenoid levels. However, studies on the effectiveness of foods in improving vitamin A status should be conducted in subjects with a marginal or deficient vitamin A status because only then will serum retinol increase. In addition, other aspects of nutritional status and nutrient intake may differ between vitamin A deficient and vitamin A replete populations. It is also important to provide additional information, for example on anthropometry and parasitic infestation, which may affect nutritional status of the subjects.

Control groups
Because changes over time could be related to factors other than the food supplement, such as seasonal variation and infection, it is necessary to include a negative control group in the study. A positive control group should be included to monitor the effect that could be achieved when conditions are most favourable, for example when synthetic β-carotene in fat or retinol is administered.

Diet of treatment groups
The diet of the treatment groups should differ only with respect to vitamin A content because other differences will confound the effect. Differences can occur, for example, when one group is given a capsule, which would not change normal food consumption, and another group is given vegetables which would reduce the consumption of vegetables normally consumed. Although it is not possible to mask foods, large differences among groups can be avoided by giving foods of the same type, for example by giving one group dark green leafy vegetables and the other group cabbage. Even better would be to offer such vegetables in a composite food such as a lumpia.

The ideal to ensure that the consumption of other foods remains unchanged when the intake of a particular food is increased, is achieved by providing subjects with all their food for the entire study period. However, this cannot be realized in most settings. The best alternative is to explain to participants the importance of not changing their normal diet and to introduce a similar dietary change in all groups. The latter option reduces the risk that changes in food consumption will differ among groups. When a similar change in food consumption occurs in all groups, a negative control group will correct for such change. An even better solution would be, if supplying all the food is not possible, to supply a large part of the diet as this would markedly reduce compensation with other foods. To check whether indeed no unwanted dietary changes occurred during the study period within and between groups, as much information as possible should be obtained about food consumption of participants before and during the intervention.

Allocation of treatment
Ideally, subjects should be randomly allocated to treatment groups. However, when the treatment is not masked, this can lead to problems as subjects will be aware of the different treatments in the study. As mentioned before, when a large part of the diet is provided under close supervision, the possibility for substantial compensation may be very small. This would especially be the case when portions of particular vegetables or fruits are significantly larger than normal daily intake. If control over the diet is smaller, groups should better not be in contact with one another. In that case, however, care has to be taken to ensure that the groups do not differ in any parameter which may invalidate conclusions from the study. It could, for example, be decided to allocate treatment by village or school after making sure that the treatment groups indeed do not differ from each other in important aspects.

Composition of food supplements
In general, the carotenoid content of foods as reported in food composition tables provides an overestimate, often two-fold, of the content measured by modern techniques such as high-performance liquid chromatography (HPLC) (West & Poortvliet, 1993). Thus, the carotenoid content of the prepared supplements should be analysed, preferably by HPLC as this technique can also provide data on the content of a range of carotenoids including isomers which differ in provitamin A activity. Further, the fat content of the supplement should be determined, and the preparation method and the matrix of the supplements described.

The design aspects described above apply to studies which test whether there is any effect of particular foods or food groups on vitamin A status. Because any intervention aimed at improving vitamin A status ultimately aims at reducing morbidity and mortality, these endpoints should be considered when evaluating large community interventions.

Should vitamin A deficiency be combated with a food-based approach?

Many uncertainties still remain about the capacity of carotene-rich fruits and vegetables to improve vitamin A status and about the bioavailability of dietary carotenoids in general. These uncertainties need to be removed if we wish to reach the goal agreed upon by all national governments, namely to eliminate vitamin A deficiency by the year 2000 (FAO/WHO, 1992). Meanwhile, we should continue to use strategies proved to be effective: vitamin A supplementation, food fortification, and consumption of retinol-rich foods and red palm oil. Home garden programmes should be continued because they have a much broader role then just providing vegetables for household consumption. Even if vegetables contribute little to improvement of vitamin A status, they still provide other nutrients and add variety to the diet. When more is known, preparation methods could be developed that improve carotene bioavailability and thus possibly the effectiveness of vegetables. Where home garden programmes include poultry, small animal husbandry or fish, like in the VAC programme in Vietnam (Giay & Dat, 1986), the consumption of such foods, especially eggs, livers and whole fish (with the liver), should be encouraged.

In order to develop locally feasible and acceptable food-based approaches to combat vitamin A deficiency, each region, province or country should identify acceptable and affordable dietary sources of retinol and carotenes, with high bioavailability, including processed and fortified foods. The effectiveness of these foods should be evaluated by intervention studies. Operational research should be done to investigate ways of achieving sufficient consumption of an array of effective foods and to measure the impact on vitamin A status, morbidity and mortality in the population.

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Appendix 6

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Lack of improvement in vitamin A status with increased consumption of dark-green leafy vegetables

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Summary
There is little evidence to support the general assumption that dietary carotenoids can improve vitamin A status. We investigated in Bogor District, West Java, Indonesia, the effect of an additional daily portion of dark-green leafy vegetables on vitamin A and iron status in women with low haemoglobin concentrations (<130 g/L) who were breastfeeding a child of 3–17 months.

Every day for 12 weeks one group (n=57) received stir-fried vegetables, a second (n=62) received a wafer enriched with β-carotene, iron, vitamin C, and folic acid, and a third (n=56) received a non-enriched wafer to control for additional energy intake. The vegetable supplement and the enriched wafer contained 3·5 mg β-carotene, 5·2 mg and 4·8 mg iron, and 7·8 g and 4·4 g fat, respectively. Assignment to vegetable or wafer groups was by village. Wafers were distributed double-masked. In the enriched-wafer group there were increases in serum retinol (mean increase 0·32 [95% CI 0·23–0·40] μmol/L), breastmilk retinol (0·59 [0·35–0·84] μmol/L), and serum β-carotene (0·73 [0·59–0·88] μmol/L). These changes differed significantly from those in the other two groups, in which the only significant changes were small increases in breastmilk retinol in the control-wafer group (0·16 [0·02–0·30] μmol/L) and in serum β-carotene in the vegetable group (0·03 [0–0·06] μmol/L). Changes in iron status were similar in all three groups.

An additional daily portion of dark-green leafy vegetables did not improve vitamin A status, whereas a similar amount of β-carotene from a simpler matrix produced a strong improvement. These results suggest that the approach to combating vitamin A deficiency by increases in the consumption of provitamin A carotenoids from vegetables should be re-examined.

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Introduction
Vitamin A supplementation and food fortification have beneficial effects on child mortality and morbidity.[1,2] Supplementation of children and pregnant women with anaemia and vitamin A deficiency increases not only serum retinol but also haemoglobin concentrations.[3,4] Vitamin A supplements given to women shortly after delivery increase serum and breastmilk retinol concentrations.[5]

Of the strategies to reduce vitamin A deficiency, the dietary approach is increasingly being emphasised because it is sustainable, provides nutrients other than vitamin A, and adds variety to the diet. In developing countries, fruit and vegetables provide 70–90% of total vitamin A intake from their high content of provitamin A carotenoids.[6] However, studies on the effectiveness of vegetables and fruits to prevent vitamin A deficiency are scarce.[7] One well-controlled study[8] showed an increase in serum retinol after consumption of red sweet potato and dark-green leafy vegetables[8] but other intervention studies that have shown positive results were controlled poorly or not at all, while cross-sectional and case-control studies had weak designs.[7]

We examined the extent to which an additional daily portion of local dark-green leafy vegetables can improve vitamin A status in anaemic breastfeeding women in a rural area in West Java, Indonesia. The effect on iron status was also examined. The women receiving vegetables were compared with others given a wafer enriched with β-carotene, iron, vitamin C, and folic acid, so that we could examine the effect of a similar amount of micronutrients in a simpler matrix with better bioavailability. A third group received a non-enriched (control) wafer to allow for effects of additional energy intake.

Subjects and methods
Subjects
The study was carried out from September, 1993, to January, 1994, in two neighbouring villages in Bogor district, West Java. Most inhabitants are of middle or low socioeconomic class. The area is free of malaria. A large variety of fruits, vegetables, and staples are available all year. The usual daily diet consists of two to three rice-based meals with vegetables and dried salted fish, soya products, or meat, and one or more snacks (fried banana, noodles, and cookies). Many breastfeeding women do not eat fruits for 6 months after delivery, believing them to be harmful to their health.

Power calculations, based on within-individual changes from a previous study of pregnant women,[4] showed that the number of subjects per group required to detect a 0·12 μmol/L difference between the groups in change of serum retinol concentration was 55 and to detect a 5 g/L difference in change of haemoglobin concentration was 49, with a power of 0·90 and α of 0·05. To allow for 15% dropouts, we decided to recruit three groups each of 65 subjects. In the two villages, more than 95% of all women breastfeeding a child younger than 18 months (n=730) were screened for anaemia (haemoglobin <120 g/L) with the Hemocue device (Angelholm, Sweden). We selected women with anaemia (58% of the total) because they are more likely to have low serum retinol concentrations.[4] They were asked to provide two samples of faeces. 294 (72%) women did so and became eligible for the study. For each of the ten administrative areas of the village assigned wafers (8000 inhabitants), eligible women were ranked by age of the breastfed child and assigned alternately to enriched or control wafers. Eligible women in the vegetable-assigned village (6000 inhabitants) were matched to the women in the wafer-assigned village for age of the breastfed child, with equal distribution over the eight administrative areas. The groups did not differ in parasitic infestation. When a woman could not participate, another eligible woman from the same area with a breastfed child of similar age was invited. Of the 256 women approached, 191 were enrolled in the study. The main reasons for non-participation were: increased haemogoblin at baseline blood collection (11%), logistic difficulties (7%), and refusal (6%). The women enrolled were breastfeeding children aged 3–17 months, and had baseline packed-cell volumes below 0·38 and baseline haemoglobin below 130 g/L. (Because of difficulties with the baseline haemoglobin measurement, we were unable to comply strictly with our enrolment criterion for haemoglobin of <120 g/L.)

All participants gave written informed consent, and the study was approved by the medical ethics committee of the Ministry of Health, Indonesia, and the Indonesian Institute of Science.

Supplements

To avoid changes in food consumption due to knowledge of the other treatment, assignment to treatment groups was by village. A study during the previous year (unpublished) had shown that within-village differences in food consumption and nutritional status of breastfeeding women were larger than between-village differences. Supplements were provided 5 days per week for 12 weeks.

Vegetable supplements were stir-fried according to local recipes, one for each day of the week. They consisted of 100–150 g vegetables per portion—cassava leaves (*Manihot utilissima*), water spinach (*Ipomoea aquatica*), spinach (*Amaranthus viridis*), or carrots (*Daucus carota*). In the other village, wafers were delivered personally each day by village volunteers. The enriched wafer contained β-carotene, vitamin C, folic acid, and iron. The taste and appearance of the enriched and control wafers were identical but the foil wrappings were different (red or blue), which permitted double-masked distribution. The code of the wrapping was known only to the manufacturer (General Biscuits, Netherlands) until after data analysis.

Special care was taken to ensure consumption of the supplements and to avoid replacement of part of the usual diet by the supplement. Consumption of all supplements was observed and vegetable portions were given to subjects in the early morning when they would not replace vegetable dishes prepared by the participants. When participants were absent from the village, they were given replacement vegetable portions on weekend days or wafers to be consumed on the days spent away from home. Participants were carefully informed about the purpose of the study and the importance of not changing the usual diet. Possible changes in food consumption, especially of vegetables, were checked by assessing food consumption before the intervention and in the 7th week, by means of a 24 h recall questionnaire administered on 2 consecutive days to a subgroup (n=108). 54 women from the vegetable group were compared with 54 women drawn equally from both wafer groups, because no difference in adaptation was expected between those receiving the two types of wafer.

Methods

Samples of blood and urine were collected from each participant at baseline (1 day before the intervention) and at follow-up (1 day after consumption of the last supplement). Breastmilk samples were collected 1 or 2 days before blood collection. Measurements of height at baseline and body weight with light clothing at baseline and follow-up were all made by the same person. For each subject, baseline and follow-up samples were analysed in the same run for each substance. Samples were coded to conceal treatment group.

Breastmilk was collected in a standard way. Between 0800 and 1100 h all milk from one breast, which had not been used to feed the child for at least 1 h, was collected by means of a breast pump, stored in dark-brown glass bottles, and transported to the laboratory on ice. Creamatocrit was measured in triplicate and averaged. Fat content was related to that measured by extraction, based on measurements by both methods made on 22 breastmilk samples. Breastmilk was stored at −20°C (2–6 weeks) then at −80°C until analysis of retinol. The samples were analysed in a room illuminated with yellow light. 500 μL samples were incubated overnight at room temperature with 500 μL ethanolic (50% by volume) potassium hydroxide (4 mol/L). 2 mL acetonitrile with 5% acetic acid was added. After separation, 50 μL of the upper layer was drawn off and subjected to high-performance liquid chromatography (HPLC). Vitamin A was detected spectrophotometrically at 325 nm and quantified by relating the peak area to a calibration curve constructed from standards analysed in the same run. Within-run and between-run coefficients of variation were 3·4% and 4·5%. Recovery in the method was 95–105%.

Blood—For the modified-relative-dose-response (MRDR) measurement, participants were asked not to eat vitamin-A-rich foods after the evening meal on the day before blood sampling. At 0730 h the next morning they were given 8·8 μmol 3,4-didehydroretinol acetate in 250 μL corn oil, followed by a snack high in fat and low in vitamin A. 5 h later subjects were physically examined and 6 mL blood was drawn from an antecubital vein, placed on ice, and protected from light. Haemoglobin concentrations were measured, at first with the Hemocue device, but we found it gave erratic results when the seal of the bottle of cuvettes had been broken for more than a few days (probably because of the warm and humid climate). During initial screening for anaemic women, this problem did not arise because all cuvettes in a bottle were used within 1 or 2 days. After a third of the subjects' haemoglobin concentrations had been measured at baseline with the Hemocue, those of other subjects were measured by the cyanmethaemoglobin method. During the third week, haemoglobin concentration was measured by this method in all subjects; it was found not to differ from the values measured at baseline (95% CI for difference −1·4 to 1·8 g/L, n=117). White blood cells were counted and zinc protoporphyrin concentration was measured (Proto-Fluor-Z, Helena Laboratories, Beaumont, Texas, USA).

Serum—Remaining blood was centrifuged, and serum was frozen for HPLC analysis of retinol and dehydroretinol[9] (within-run coefficients of variation 5·1% for retinol, 10·4% for dehydroretinol, 9·5% for dehydroretinol/retinol ratio). Serum carotenoids were measured by HPLC[10] (within-run and between-run coefficients of variation 3·4% and 8·2% for β-carotene, 4·6% and 7·0% for α-carotene, 3·6% and 11·4% for β-cryptoxanthin, 5·7% and 6·6% for lutein, and 9·6% and 9·3% for zeaxanthin). Serum ferritin was measured by radioimmunoassay (Ciba Corning, Medfield, Massachusetts, USA), serum transferrin receptor by ELISA,[11] and serum albumin by a standard method.

Urine—Pregnancy tests were done on urine samples at baseline and follow-up and women found to be pregnant were excluded.

Faeces—Samples (562) were collected on ice from 294 women and stored at 4°C for no more than 2 days before examination for protozoa, cysts, and helminth eggs. To check the results, 17 samples with multiple infections were examined both in Bogor and at the Laboratory for Parasitology, Leiden University, Netherlands.

Supplements—Duplicate portions of vegetables (5 consecutive days, four occasions) and wafers (8 enriched, 8 control, two occasions), were analysed for fat, protein, fibre, and iron,[12,13] and carbohydrate was calculated by difference. Carotenoids were measured in vegetable portions[14] and β-carotene in wafers.[15] The α-carotene content of the wafers was estimated from information

	Vegetables	Enriched wafer	Control wafer
Carotenoids (mg)			
All-*trans* β-carotene	3·5	3·5	0·1
α-carotene	0·4	<0·1*	··
Lycopene	ND	··	··
β-cryptoxanthin	ND	··	··
Lutein and zeaxanthin	5·5	0	0
Micronutrients (mg)			
Iron	5·2	4·8	0·4
Vitamin C	11·4	21·5	0·2
Folic acid	0·13	0·10	0
Major nutrients (g)			
Fat	7·8	4·4	4·5
Protein	3·1	0·8	0·8
Carbohydrates	2·7	7·3	7·6
Dietary fibre	3·6	0·1	0·4
Energy (kJ)	395	304	315

*Estimated. Results averaged from analysis of individual samples, expressed per 1-day portion. ND=not detected. Some analyses were not done on wafers since the nutrients were not added to the wafers.

Table 1: **Composition of supplements**

	Vegetable group (n=57)	Enriched-wafer group (n=62)	Control-wafer group (n=56)
Demographic and anthropometric data			
Age breastfed child (months)	8·9 (3·9)	8·9 (4·3)	8·9 (4·0)
Parity	5·0 (3·4)*	5·0 (2·9)	4·6 (2·6)*
Body weight (kg)	46·1 (4·9)	46·4 (5·5)	48·1 (6·9)
Height (m)	1·48 (0·05)†	1·49 (0·05)	1·51 (0·06)
Body-mass index (kg/m²)	21·1 (1·9)	20·9 (2·1)	21·2 (2·7)
Weight change (kg), baseline to follow-up	−0·5 (1·5)	−0·4 (1·3)	−0·3 (1·4)
Parasitic infection (% with positive stool)‡			
Ascaris	82	84	80
Trichuris	93	95	88
Giardia lamblia	2	8	7
Entamoeba histolytica	29	26	25
Hookworm	0	5	5

Data presented as mean (SD) or % of group. *1 woman was breastfeeding twins. †p<0·05 *vs* control-wafer group (ANOVA). ‡Data missing for 1 woman in vegetable group.

Table 2: **Characteristics of participants at baseline**

supplied by the manufacturer of the β-carotene used in the wafers. Vitamin C[16] and folic acid (microbiological assay with *Lactobacillus casei*, coefficient of variation 8·9%) were measured in vegetables and wafers. Results of the analyses are shown in table 1.

Food intake—For the 24 h recall questionnaire, amounts of the wafer and vegetable supplement were not recorded. Where possible, duplicate portions of rice were weighed to the nearest gram. Carotenoid content was taken from a table of foods from developing countries,[17] and content of other nutrients from local food-composition tables (references available from CEW). The Micronap programme (Northern Technical Data Inc, Winnipeg, Canada) was used for all calculations.

Statistics

To examine differences between groups, analysis of covariance was used for normally distributed variables and the Mann-Whitney test (two groups) or Kruskal-Wallis test (three groups) for non-normally distributed variables. Changes from baseline to follow-up were calculated for each individual by subtraction, even for variables with skewed distributions, because the calculated changes were normally distributed. To compare baseline and follow-up values within treatment groups, a paired *t* test was used for all variables except intake of foods rich in vitamin A (excluding supplements), for which Wilcoxon's signed-rank test was used because many subjects did not consume the foods of one or more subgroups. To compare calculated changes from baseline to follow-up among treatment groups, with control for other factors, analysis of covariance was used with dummies for treatment groups.[18] In addition, when the variation of calculated changes differed greatly between groups, analysis of covariance was used to compare two groups with similar variation.

Results

Follow-up data were obtained from 175 (91·6%) women. 5 women had become pregnant, 3 had moved away from the study area, the breastfed child of 1 had died, 1 woman had excessive menstrual blood loss, and 6 women refused further participation. Apart from a small difference in height, the characteristics of the remaining subjects did not differ among the groups (table 2).

Serum albumin concentrations ranged from 32 to 56 g/L, a little lower than the normal range (40–60 g/L). The range of leucocyte counts (4·0–10·4×10⁹/L) was close to the normal range (3·2–9·8×10⁹/L). Based on these findings and on the absence of signs of infection at clinical examination, no subject was excluded from data analyses.

Food consumption

During the intervention period, there was no change in food availability in the study area. Intake of macronutrients and iron (table 3) did not change significantly during the intervention (supplements excluded) in the vegetable group or in the combined wafer group (there were no differences between the two wafer groups). Baseline carbohydrate intake, and thus the proportion of energy from various nutrients, differed between the vegetable and combined wafer groups, but this difference is unlikely to affect vitamin A status. During the intervention, carbohydrate intake was similar in the two groups.

Because the very large day-to-day variation of vitamin A intake made it difficult to assess changes in this variable with a 24 h recall questionnaire, changes were examined also in terms of vegetable and fruit intake (table 4). Intake during the intervention, excluding supplements, did not differ from that at baseline in either group. The combined wafer group consumed more non-

	Vegetable group (n=50)		Combined wafer group (n=54)	
	Baseline mean (SD)	Change (95% CI)	Baseline mean (SD)	Change (95% CI)
Energy (MJ)	10·2 (2·7)	0·4 (−0·6 to 1·3)	10·7 (3·3)	0·5 (−1·4 to 0·5)
Protein				
Weight (g)	65 (20)	−4 (−11 to 3)	63 (20)	−3 (−8 to 2)
% of energy	10·9 (1·9)*	−0·9 (−1·6 to −0·3)*	10·2 (1·6)	0 (−0·6 to 0·5)
Fat (g)				
Weight (g)	73 (20)	0 (−11 to 11)	63 (24)	6 (−3 to 14)
% of energy	27·0 (8·0)†	−1·3 (−3·9 to 1·3)*	22·7 (6·9)	2·6 (0·7 to 4·6)
Carbohydrates				
Weight (g)	376 (111)*	29 (−12 to 70)*	431 (155)	−31 (−74 to 12)
% of energy	64·1 (7·4)†	2·3 (−0·4 to 4·9)*	68·5 (6·6)	−1·6 (−3·6 to 0·4)
Iron (mg)	13 (6)	−2 (−3 to 0)	13 (6)	0 (−2 to 2)

Supplements excluded. *p<0·05, †p<0·01 for difference between vegetable and combined wafer group (ANOVA).

Table 3: **Daily intake of macronutrients and iron and change from baseline to 7th week of intervention in subgroup who answered 24 h recall questionnaire**

	Median (interquartile range) intake			
	Vegetable group (n=50)		**Combined wafer group (n=54)**	
	Baseline	Intervention	Baseline	Intervention
Green leafy vegetables				
Weight (g)	44 (4–117)	38 (0–90)	50 (11–78)	33 (2–81)
Vitamin A content (RE)	137 (9–447)	117 (0–403)	136 (27–373)	111 (11–271)
Non-leafy red and yellow vegetables				
Weight (g)	24 (15–53)	29 (12–68)	26 (13–62)	37 (21–65)
Vitamin A content (RE)	9 (5–59)	17 (10–109)	18 (10–81)	21 (12–128)
Non-leafy green vegetables				
Weight (g)	3 (0–43)*	5 (0–34)	32 (2–87)	14 (2–41)†
Vitamin A content (RE)	2 (0–11)*	3 (0–9)	8 (1–24)	4 (1–10)†
Fruits				
Weight (g)	0 (0–65)	0 (0–65)‡	0 (0–38)	55 (0–86)†
Vitamin A content (RE)	0 (0–8)	0 (0–8)‡	0 (0–5)	8 (0–14)†
Total carotenoids (RE)	337 (124–605)	289 (37–597)	351 (132–558)	273 (137–575)
Total retinol (RE)	19 (8–53)	13 (5–43)	16 (6–33)	12 (5–29)

Supplements excluded. *Differed significantly ($p<0·05$) from baseline value of wafer group. †Differed significantly ($p<0·05$) from baseline within group. ‡Differed significantly ($p<0·05$) from follow-up value of wafer group.

Table 4: **Daily intake of carotenoids, retinol, and groups of vegetables and fruits by weight and vitamin A content at baseline and in 7th week of intervention**

leafy green vegetables at baseline and more fruits during the intervention. However, these differences are unlikely to have had much impact on vitamin A status. Total vitamin A intake did not differ between the groups.

Vitamin A status

3% of women had deficient serum retinol concentrations (<0·35 μmol/L) and 33% had marginal values (0·35–0·70 μmol/L). Breastmilk concentrations were deficient in 7% and marginal in 39%. There were no significant differences between the groups at baseline (table 5).

During the intervention, serum retinol increased significantly (38%) in the enriched-wafer group; this change differed significantly from those in the other two groups (figure). Similarly, the substantial increase in breastmilk retinol in the enriched-wafer group (67%) differed significantly from the changes in the other two groups ($p<0·01$, ANOVA).

Serum β-carotene concentration increased by 390% in the enriched-wafer group and by 17% in the vegetable group; there was no significant change in the control-wafer group. In terms of change in serum β-carotene concentration, the vegetable group and the control-wafer group differed significantly ($p<0·01$) from each other only when analysis of covariance was done irrespective of the large variation in response in the enriched-wafer group.

Changes in the serum concentrations of carotenoids other than β-carotene were very small (table 5). Serum β-cryptoxanthin concentrations did not change significantly in any group. Serum α-carotene increased more in the enriched-wafer group than in the other groups, whereas the changes in serum lutein and zeaxanthin in the vegetable group differed from those of the other groups ($p<0·01$).

At baseline, 68% of the women had dehydroretinol/retinol ratios above 0·06, indicating low vitamin A status,[9] but there were no differences in the ratio among the groups (table 5). There was a significant ($p<0·001$) decrease in the dehydroretinol/retinol ratio in the enriched-wafer group but not in the other two groups. The change in the enriched-wafer group was therefore significantly different from that in the other two groups. The small significant difference ($p<0·05$) between the vegetable group and the control-wafer group was related to a slightly higher ratio in the vegetable group at baseline (mean 0·12 *vs* 0·10). Analysis of the difference between the two groups corrected for baseline value showed no difference.

Iron status

At baseline, the only difference between the groups in iron status variables was in the transferrin receptor concentration, which was slightly higher in the vegetable group than in the control-wafer group (table 6). The changes during the intervention did not differ among the groups. At follow-up, haemoglobin concentration was significantly higher and serum transferrin receptor concentration significantly lower in all three groups. The transferrin receptor level reflects iron requirements at tissue level. The increase in packed-cell volume and the

	Vegetable group (n=53–57)		**Enriched-wafer group (n=58–62)**		**Control-wafer group (n=53–54)**	
	Mean (SD) at baseline	Mean (95% CI) change	Mean (SD) at baseline	Mean (95% CI) change	Mean (SD) at baseline	Mean (95% CI) change
Serum retinol (μmol/L)†	0·89 (0·04)	0·06 (−0·01 to 0·14)	0·84 (0·04)	0·32 (0·23–0·40)*	0·81 (0·04)	0·02 (−0·04 to 0·09)
Breastmilk retinol ((μmol/L)‡	0·98 (0·92)	−0·04 (−0·31 to 0·23)	0·88 (0·59)	0·59 (0·35–0·84)*	0·84 (0·51)	0·16 (0·02–0·30)*
Serum β-carotene (μmol/L)†	0·19 (0·12)	0·03 (0–0·06)*	0·19 (0·12)	0·73 (0·59–0·88)*	0·17 (0·09)	−0·02 (−0·04 to 0·01)*
Serum α-carotene (μmol/L)‡	0·07 (0·04)	0·01 (0–0·02)*	0·06 (0·03)	0·03 (0·02–0·04)*	0·06 (0·03)	0 (−0·01 to 0·02)
Serum β-cryptoxanthin (μmol/L)	0·08 (0·07)	0·02 (−0·01 to 0·04)	0·07 (0·06)	−0·01 (−0·02 to 0·01)	0·06 (0·04)	0 (−0·01 to 0·01)
Serum zeaxanthin (μmol/L)§	0·11 (0·05)	0·01 (0–0·02)	0·10 (0·05)	−0·01 (−0·03 to 0)*	0·11 (0·05)	−0·02 (−0·03 to 0)*
Serum lutein (μmol/L)§	0·48 (0·27)	0·05 (−0·01 to 0·11)	0·47 (0·24)	−0·12 (−0·18 to −0·06)*	0·43 (0·19)	−0·06 (−0·11 to −0·01)*
Median (IQR) DR/R ratio	0·09 (0·05–0·15)	−0·01 (−0·03 to 0)	0·07 (0·04–0·11)	−0·03 (−0·05 to −0·01)*	0·09 (0·04–0·13)	0·02 (−0·01 to 0·4)

DR/R=dehydroretinol/retinol ratio (n=47, 52, 49 for vegetable, enriched-wafer, control-wafer groups). *Significantly different from baseline ($p<0·05$). †,‡ For comparisons between groups, change in enriched-wafer group was greater than changes in other groups (ANOVA, control for age of breastfed child, individual weight change, and (for breastmilk) milk fat changes; †$p<0·001$, ‡$p<0·01$. §Vegetable group differed from other groups in change from baseline (ANOVA).

Table 5: **Vitamin A status at baseline and changes from baseline to 12 weeks**

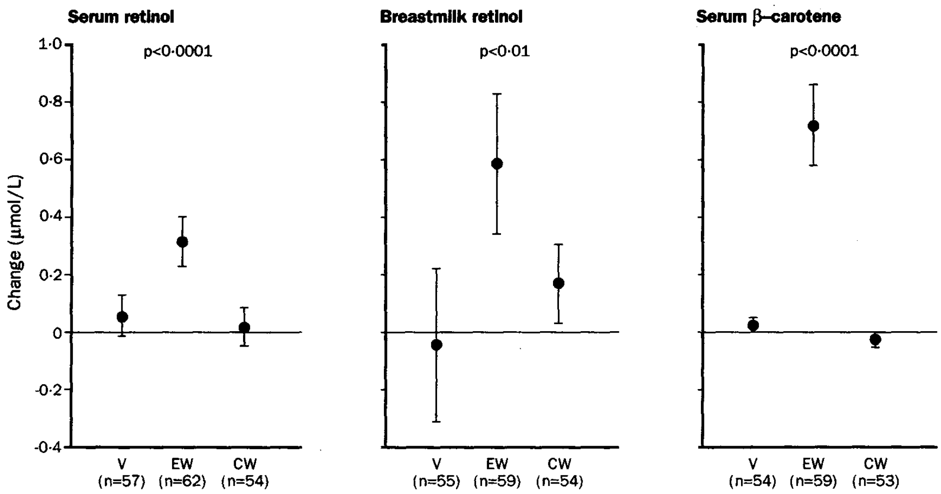

Figure: **Changes in serum retinol and β-carotene and breastmilk retinol concentrations from baseline to 12 weeks in vegetable (V), enriched-wafer (EW), and control-wafer (CW) groups**

Mean and 95% CI. p values for difference from other two groups (ANOVA), controlled for age of breastfed child, individual weight change, and for breastmilk, milk fat changes.

decrease in zinc protoporphyrin concentrations reached statistical significance in two groups. A decrease in zinc protoporphyrin shows a reduction of iron shortage in red blood cells. The trend of increased serum ferritin concentration in all groups suggests increased iron stores. The changes in iron status could be explained by the fact that the women were recovering from iron loss resulting from pregnancy and delivery, and also by regression to the mean, because a low haemoglobin concentration was one of our selection criteria.

Among women with low (<0·70 µmol/L) serum retinol concentrations at baseline, packed-cell volume increased significantly ($p<0·05$) more in the 20 women who received the enriched wafer (0·02 [0·01–0·02]) than in 24 who received the control wafer (0 [−0·01 to 0·01]) or in 18 who received vegetable supplements (0 [0–0·01]).

Discussion

Our results indicate that β-carotene is very poorly absorbed from dark-green leafy vegetables, but that absorption from an enriched wafer is good. The vitamin A status of women who received the enriched wafer improved substantially but there was no improvement in the vegetable or control-wafer groups. The smaller increase in serum than in breastmilk retinol in the enriched-wafer group is possibly due to more precise homoeostatic control of retinol concentrations in serum than in breastmilk. In this study population with a wide age range of the breastfed children, the variation in serum retinol response was smaller than that in breastmilk retinol response; serum retinol is therefore a more sensitive indicator of change of vitamin A status. Expression of the breastmilk retinol concentration per gram of milk fat did not affect the within-individual variation in retinol content. A high proportion of the women in this study, 36%, had deficient or marginal serum retinol concentrations, perhaps partly because anaemia was a selection criterion[4] and because the women were at a late stage of lactation.[5]

The increase in serum β-carotene concentration in the vegetable group was too small to have had much impact on nutritional status. Serum concentrations of provitamin A carotenoids (α-carotene and β-cryptoxanthin) did not change. The small increase in serum α-carotene in the enriched-wafer group could be due to α-carotene in the β-carotene preparation used to enrich the wafer, or to β-carotene supplementation itself.[19]

Vitamin A supplementation of anaemic subjects with low vitamin A status can increase packed-cell volume and haemoglobin concentration.[3,4] In this study, although vitamin A status improved in women who received the enriched wafer, iron status did not improve in any treatment group. For women with baseline serum retinol below 0·70 µmol/L, however, the increase in packed-cell volume was greater in the enriched-wafer group than in the other groups. Increases in haemoglobin showed a similar, but not significant, trend. A possible explanation for the smaller difference in iron status changes between

	Vegetable group (n=55–57)		**Enriched-wafer group (n=61–62)**		**Control-wafer group (n=55–56)**	
	Baseline	Change (95% CI)	Baseline	Change (95% CI)	Baseline	Change (95% CI)
Packed-cell volume*	0·35 (0·02)	0·01 (0–0·01)‡	0·34 (0·03)	0·01 (0·01–0·02)‡	0·35 (0·02)	0 (0–0·01)
Haemoglobin (g/L)*	110 (10)	8 (6–10)‡	108 (10)	9 (7–12)‡	109 (10)	8 (5–10)‡
Zinc protoporphyrin* (µmol/mol heme)	89 (46)	−7 (−13 to −1)§	92 (45)	−8 (−14 to −1)§	77 (23)	−1 (−4 to 2)
Serum ferritin (µg/L)†	9·0 (2·3–25·8)	3 (−1 to 7)	8·5 (2·8–20·0)	2 (−1 to 5)	10·0 (3·0–25·5)	2(−1 to 7)
Serum transferrin receptor (mg/L)†	4·83 (3·59–5·95)	−0·56 (−0·9 to −0·21)‡	4·45 (3·65–5·65)	−0·35 (−0·64 to −0·07)§	4·08 (3·30–4·91)	−0·33 (−0·52 to 0·15)‡

Baseline values are *mean (SD) or †median (IQR). Haemoglobin values measured during week 3, rather than baseline. ‡,§Significant change from baseline: ‡$p<0·01$, §$p<0·05$.

Table 6: **Iron status at baseline and changes to 12 weeks' follow-up**

the treatment groups than was observed in previous studies[4] is that the dose of vitamin A was smaller.

The enriched wafer contained 4·8 mg carbonyl iron and 21·5 mg vitamin C, which could be expected to improve iron status. The bioavailability of carbonyl iron is similar to that of ferrous sulphate,[20] but it may be reduced by inclusion in foods.[21] The vegetable supplement contained 5·2 mg iron and 11·4 mg vitamin C, but bioavailability of iron in vegetables is low.[6] The iron content of our supplements may have been too low to affect iron status.

We established before this study that nutritional status and food consumption of breastfeeding women in the two neighbouring villages were similar. Allocation to treatment had to be by village, because it was impossible to distribute vegetables and wafers in a double-masked way. Randomisation of treatment across villages could lead to changes in food consumption by participants because they would be aware of the other method of supplementation. We had to be sure that the vegetable portions provided were eaten and that they did not replace vegetable dishes normally consumed.

Compliance was assured by close supervision of distribution and consumption of supplements. In addition, replacement was avoided by giving the vegetable portions to the participants in the morning. Participants were informed carefully about the purpose of the study and that they could benefit from the supplements only if they did not change their diet and ate every vegetable portion or wafer supplied. Their commitment to the study is shown by the low dropout rate. In addition, the 24 h recall questionnaire, which was used to examine differences in consumption large enough to affect vitamin A status, revealed no within-group differences in intake during the intervention. Weight loss in all three groups was similar and less than expected for unsupplemented breastfeeding women,[22] which confirms that the supplements were eaten and that compliance was the same in all three groups. Subjects who gained weight and those who lost weight had almost identical changes in vitamin A status; thus differences between the treatment groups can be ascribed to the supplements. Futhermore, even if a woman did not eat one of her regular vegetable servings, the total amount of vegetables consumed that day would still be increased, because one portion of vegetable supplement contained the amount of vegetables usually consumed in two or three servings on one day.

A difference in compliance between participants would lead to a range of changes in serum β-carotene concentration. The large confidence interval of the increase of serum β-carotene in the enriched-wafer group reflects not so much a possible difference in compliance as a large between-individual variation in bioavailability of β-carotene.[23] The virtual absence of variation in serum β-carotene response in the vegetable group suggests that bioavailability was equally poor for all subjects, overshadowing any possible difference in compliance. The small increase (in relation to the two wafer groups) in serum concentrations of lutein and zeaxanthin in the vegetable group also supports the evidence that the vegetable supplements were eaten, but that carotene bioavailability was poor.

The current recommendations for consumption of fruit and vegetables to meet vitamin A requirements are largely based on the Sheffield experiment by Hume and Krebs.[24] They found that bioavailability of β-carotene from vegetables and carrots was, on average, only a third of that of β-carotene in oil. This finding was taken into account when establishing the conversion factor for dietary β-carotene—6 μg β-carotene equals 1 μg retinol or 1 retinol equivalent. The recommended daily allowance for breastfeeding women is 850 retinol equivalents.[6] In our study, vegetable portions contained 3·5 mg β-carotene (583 retinol equivalents) and α-carotene supplied an additional 33 retinol equivalents. The enriched wafer also contained 3·5 mg β-carotene, presumably with higher bioavailability. Our findings challenge the established factor for converting amounts of carotenoids in vegetables to vitamin A activity. Other studies have also suggested that the conversion factor overstates the bioavailability of β-carotene from vegetables and its conversion to vitamin A[23,25] (and Muhilal, Karyadi; unpublished).

The low bioavailability of β-carotene in dark-green leafy vegetables may be due to several factors. First, the recommended daily allowance was established in vitamin-A-deficient subjects, whereas only 3% of our study population were vitamin A deficient. In our subjects, however, the response in serum retinol was independent of baseline serum retinol, which suggests that there was no effect of vitamin A status on carotene absorption or bioconversion in this range of serum retinol concentrations. Second, physical inaccessibility of carotenoids in plant tissues may reduce their bioavailability. In green leaves, β-carotene molecules are organised in pigment-protein complexes located in cell chloroplasts, and in fruits, β-carotene is found in lipid droplets and chromoplasts. It may be difficult to free β-carotene in dark-green leafy vegetables from its matrix. Perhaps β-carotene in fruits is more bioavailable, as suggested by the seasonal variation in vitamin A status in areas where mangoes are eaten.[26] Third, carotenoids other than β-carotene in the vegetable supplement may have inhibited β-carotene absorption by competing for absorption.[27] However, the increases in serum lutein and zeaxanthin in the vegetable group were also small. Fourth, light cooking can increase bioavailability, but further cooking can produce isomers of all-*trans* β-carotene such as 13-*cis* β-carotene or 9-*cis* β-carotene with much lower provitamin A activity.[28] We did not measure *cis* β-carotene isomers in the vegetable supplement, but the carotenoid profile showed that about 30–35% of β-carotene was *cis* isomers. Analyses of raw vegetables from the same area showed that about 15% of β-carotene was *cis* isomers. Although the all-*trans* β-carotene content of the vegetable supplement and the enriched wafer was the same, isomerisation could have led to competition for absorption between all-*trans* and *cis* isomers, at the expense of all-*trans* β-carotene with higher provitamin A activity. This possibility, however, is unlikely, because the evidence of competition by other carotenoids is poor. Fifth, the amount of fat consumed with carotenoids has a strong effect on carotenoid absorption, but cannot explain our findings since the vegetable supplement contained more fat (7·8 g) than the wafer supplement (4·4 g). It is possible that β-carotene absorption is affected by the type of fat.[29] Sixth, there may have been differences between the groups in the extent of conversion of absorbed β-carotene to retinol. However, neither serum retinol nor serum β-carotene increased in the vegetable group. Other factors that might affect bioavailability, such as parasitic infestation, infection with bacteria, viruses, or protozoa, and intestinal malabsorption, cannot explain the differences between the groups.

It is unlikely that a longer intervention would have resulted in an improvement in vitamin A status. Jalal[8] provided subjects with 850 retinol equivalents daily from red sweet potato and vegetables and found an increase in serum retinol concentration after 21 days. It is possible that parasitic infestations and perhaps other factors such as competition for absorption between carotenoids exacerbate the effect of the difference in the matrix where the carotenoid is found between leafy vegetables and other carotenoid-rich foods such as red sweet potato, but we have no quantitative information to support this hypothesis.

Our findings do not support the long-standing assumption that vitamin A deficiency can be combated by increasing the intake of dark-green leafy vegetables. Consumption of vegetables should never be discouraged because they supply other valuable dietary constituents. Our results need to be confirmed and more work needs to be done on factors influencing the bioavailability of carotenoids from different foods. Other food approaches to overcoming vitamin A deficiency, such as the use of foods naturally rich in retinol (eggs, whole fish, and liver) and fortified foods, should be developed further.

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Appendix 7b

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Vitamin A status and dark green leafy vegetables

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THE LANCET

Vitamin A status and dark green leafy vegetables

SIR—de Pee and her colleagues (July 8, p 75) report no improvement in serum retinol in lactating women receiving vegetable supplements, by contrast with those given wafers containing equivalent amounts of β-carotene. de Pee et al question the conversion factor of 6:1, currently used to convert dietary carotenoids to retinol equivalents and the efficacy of such carotenoids in combating vitamin A deficiency.

It is generally agreed that a single conversion factor may not be valid for all dietary situations. However, there is no reason to doubt that increased consumption of vegetables containing provitamin A does improve vitamin A status in deficient populations. At least 11 studies including ours[1,2] from different parts of the world have demonstrated a positive impact from vegetables and fruits rich in β-carotene. Only one of these studies is cited, the others being dismissed as poorly controlled. On the other hand, there is only one other report (from Guatemala) of vegetable supplements having no effect on serum retinol.[3]

de Pee et al did not measure carotene isomers in the cooked supplements but it is possible that prolonged cooking resulted in increased formation of *cis*-isomers with lower potency. Moreover, all the earlier studies showing a positive impact were done in children with low serum-vitamin-A concentrations, the increase in retinol being greater in those with initial concentrations less than 20 μg/dL than in those with higher levels; there was no change above 30 μg/dL. These results cannot be ignored just because they are not confirmed in lactating women. Although the test used by de Pee et al suggested low vitamin A stores, only 3% of women had serum retinol concentrations in the deficient range. We are not given the data in relation to initial levels to see if retinol responses differed between those with normal and those with low concentrations.

These results cannot be extrapolated to settings where many children have retinol levels below 20 μg/dL, in whom vegetable supplements have been shown to be beneficial. Even in the Guatemalan study,[3] where the mean serum retinol was not in the deficient range and there was no change after vegetable supplementation, two children with serum retinol less than 20 μg/dL showed a positive response. Deficient populations do benefit from vegetable supplementation but the lack of response in those with normal retinol concentrations is difficult to interpret. Absorption of β-carotene and its conversion to vitamin A may be determined by the body's needs for the vitamin.

All comparative studies have shown that the increase in serum retinol is much higher with pure β-carotene or vitamin A than with food sources. This is seen with all drugs/nutrients, and synthetic vitamin A/β-carotene are no exceptions. However, this cannot be used as an argument for synthetic instead of natural sources of vitamin A. de Pee et al suggest alternative approaches using animal foods containing preformed vitamin A to overcome vitamin A deficiency. However, populations affected by vitamin A deficiency do not have access to such expensive foods. In developing countries, 80–90% of the total vitamin A intake comes from vegetables and fruits containing provitamin A carotenoids, and the evidence suggests that these carotenoids can replace vitamin A in the diet. However, their biological equivalence needs to be established. Increasing the consumption of locally available carotenoid-rich foods is the most rational strategy against vitamin A deficiency. Bioavailability is determined by several factors, including the choice of vegetables and the way they are prepared, and programmes designed to improve vitamin A status must find ways of maximising the bioavailability of dietary carotenoids.

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SIR—Despite the opening statement by de Pee et al, their results are inconsistent with several studies in children. Epidemiological studies and community-based clinical trials in children show that where vitamin A deficiency is confirmed biochemically (serum retinol <0·7 μmol/L) or clinically, provitamin A carotenoids from food, including dark-green leafy vegetables, raise serum concentrations of retinol and ward off or even correct clinical deficiency. Some studies can be criticised for lack of randomisation, lack of controls, or masking. However, one looks for consistency in results as a gauge for determining likely causality.

When initial levels are not low serum retinol does not usually respond to a food or other supplemental source of vitamin A. de Pee et al do not tell us specifically how the subset of women who had low serum values (36%) or the 46% who had deficient or marginal breast-milk concentrations were distributed among the treatment groups or how these women, who could be expected to respond, reacted to the interventions. An alternative explanation for lack of increased serum β-carotene in the vegetable-supplemented group could be very efficient bioconversion (the non-convertible carotenoids lutein and zeaxanthin increased in serum) and deposition in body stores. The methodology used was not sensitive enough to detect small changes in body stores of vitamin A.

The study be Jalal, cited by de Pee et al is a good example of a carefully masked clinical trial among children who were vitamin-A-deficient and whose vitamin status improved with vegetable sources of β-carotene, most notably when they were dewormed and the fat content of their diet was concurrently increased. de Pee et al noted a uniform distribution of parasite species among the groups but did not report intensity of infections and did not deworm the women before interventions. Nor do they think that a difference in fat intake could account for the lowered absorption of carotenoids from the vegetable-based supplement. Yet there was only 7·8 g of fat in the stir-fried vegetable supplement, and this was fed separately from any other meal component that could have provided additional fat. Presumably the fortified water, which contained 4·4 g fat, was given under the same conditions. Hence, very little fat was provided; this was probably sufficient when this small amount of β-carotene (3·5 mg) was given as a supplement in a wafer but possibly not when β-carotene was provided as part of a complex milieu in competition with other carotenoids and lipid-soluble substances released from the vegetable matrix. Jalal[4] found that fat in the amount of 15 g from supplemental foods fed daily with the vegetable-containing meals was important among vitamin-A-deficient Indonesian children fed carotene from vegetable sources, including spinach. Other studies in adults show that supplements of β-carotene require dietary fat for absorption and that

Appendix 7b

supplement absorption is enhanced by administering them with meals.[15] Insufficient fat, and perhaps intense parasite infection, could be reasons for the lack of improvement in vitamin A status among the vegetable-supplemented group in de Pee's. If so, dark-green leafy vegetables should not be labelled as ineffective.

Much remains to be learned about the biochemistry of factors affecting bioavailability, bioconversion, and control over serum and breast-milk levels of retinol and carotenoids, and the sensitivity of indicators of change in vitamin A status. While pursuing studies to clarify these biochemical indices, every effort should be made to increase the accessibility to and consumption of food sources of carotenoids, including dark-green leafy vegetables. Experience shows this to be an effective approach to preventing vitamin A deficiency, even if the science to document it unequivocally has still some way to go.

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Authors' reply

SIR—Reddy and Underwood raise several important issues. Questions about how comparable the three groups were initially are answered in table 5 of our paper, showing that the distributions of retinol concentrations in serum and in breastmilk at baseline were similar. Also, the proportion of women with deficient or marginal levels of retinol in serum were the same in the vegetable and enriched-wafer groups, and slightly higher in the control-wafer group (table). With the same cutoff for breastmilk retinol as for serum retinol, the proportions of women with deficient/marginal levels were similar in the three groups. We have now examined the responses of women in subgroups drawn on the basis of marginal levels of retinol in serum and in breastmilk (table). In all three subgroups with deficient/marginal serum retinol the serum retinol concentration rose. The improvement in the enriched-wafer subgroup differed significantly from that of the other two subgroups. However, the improvement in the vegetable and control-wafer subgroups did not differ from one another, indicating regression to the mean. This highlights the importance of having a negative control group. The subgroups with deficient/marginal breast milk retinol displayed changes in breast milk retinol similar to the pattern seen with serum retinol. The relatively high vitamin A status of the participants in our study is unlikely to explain the lack of effect we observed.

Duplicate portions of vegetable supplements were sampled after preparation—ie, the composition data are on supplements as consumed. Only the all-*trans*-isomer of β-carotene was measured. The content was the same in the prepared vegetable supplement and the enriched water (table 1 of paper). In the discussion we noted that *cis*-isomers of β-carotene in the vegetable supplement provided an estimated additional 30–35%.

Several types of study on intake of provitamin A carotenoids from vegetables and fruits and vitamin A status do indeed point to an association but only intervention studies can test whether the relation is causal or not. Of the 16 intervention studies reported and discussed in our review[1] (advanced copies have been widely distributed), 13 showed a positive effect on vitamin A status while 3 studies showed no effect. In our view 14 have weaknesses, such as no or small negative control groups, untreated controls, high and unexplained drop-out rates, no baseline data, or very few participants with very variable responses so that unequivocal conclusions cannot be drawn. A weak design does not justify ignoring results of a study but the results do need to be confirmed in well-designed studies.

2 studies, discussed by Underwood and Reddy, were designed well. Bulux and co-workers[2] did not find an improvement of serum β-carotene levels in children given carrots but did find an improvement in those fed purified β-carotene despite the fact that the children were not vitamin A deficient. Jalal's study[3] reported an improvement of vitamin A status in children fed red sweet potato and dark green leafy vegetables. Red sweet potato was the major source of provitamin A carotenoids (personal communication).

What about possible explanations for the lack of an effect of dark green leafy vegetables? A very efficient rate of bioconversion of β-carotene to retinol in the vegetable group but not in the wafer group is unlikely. The groups were well matched with a similar proportion of women with marginal retinol levels in serum or breast milk initially. The extensive absorption and/or bioconversion of β-carotene would be expected to result in increased retinol levels in serum and breast milk and/or increased serum β-carotene levels in the vegetable and the wafer groups.

The parasite load was high; in many stools we found >1000 *Ascaris* eggs per 25 mg. A high parasite load may make the freeing of β-carotene more difficult from a complex matrix (vegetables) than from a simpler one (wafer). Deworming medication is not often taken and we decided not to deworm the women before the intervention.

The fat content of the vegetable supplement (7·8 g) was high. The study by Jayarajan, Reddy, and co-workers, which is often cited, found that 5 g oil added to spinach and rice resulted in a larger increment in vitamin A status than the same meal without fat. In our case the fat accounted for 75 energy % of the vegetable supplement, while in the normal diet fat accounted for 25%. When the vegetable supplement would have been taken as part of a complete meal, the relative fat content of the meal would have been smaller and

	Vegetable		Enriched wafer		Control wafer	
	Total	Subgroup	Total	Subgroup	Total	Subgroup
Serum retinol (μmol/L)	(n=57)	(n=19)	(n=62)	(n=20)	(n=54)	(n=24)
Baseline (SD)	0·89 (0·33)	0·54 (0·16)	0·84 (0·31)	0·53 (0·13)	0·81 (0·32)	0·56 (0·10)
Change (95% CI)†§	0·06 (−0·01–0·14)	0·17 (0·06–0·29)*	0·32 (0·23–0·40)*	0·40 (0·23–0·51)*	0·02 (−0·04–0·09)	0·09 (0·01–0·17)*
Breast milk retinol (μmol/L)	(n=55)	(n=28)	(n=59)	(n=29)	(n=54)	(n=26)
Baseline (SD)	0·98 (0·92)	0·44 (0·16)	0·88 (0·59)	0·49 (0·14)	0·84 (0·14)	0·49 (0·13)
Change (95% CI)‡§	−0·04 (−0·31–0·23)	0·36 (0·18–0·53)*	0·59 (0·35–0·84)*	0·94 (0·60–1·28)*	0·16 (0·02–0·30)	0·35 (0·21–0·49)*

Subgroups comprise women with baseline concentrations of retinol in serum or in breast milk <0·70 μmol/L. Baseline values are mean (SD); in our paper SE values for serum retinol at baseline were reported instead. *Significantly different from baseline (p<0·05). For comparison between groups, change in enriched-wafer group was greater than changes in other groups (ANOVA, control for age of breastfed child, individual weight change, and [for breast milk] milk fat changes: †p<0·001; ‡p<0·01 for total groups; §p<0·001 for subgroups.

Table: **Concentration of retinol in serum and breast milk at baseline and the change from baseline to 12 weeks** interference of other components in the diet would have been greater.

We agree that often animal foods cannot play a major part in sustainable strategies against vitamin A deficiency. They are too expensive. This fact was the basis for our study, which was designed to measure the extent to which vegetables can improve vitamin A status. We also agree that our findings need to be examined carefully because of the policy implications.

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Appendix 8

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Orange fruit is more effective than are dark-green, leafy vegetables in increasing serum concentrations of retinol and β-carotene in schoolchildren in Indonesia[1–3]

Saskia de Pee, Clive E West, Dewi Permaesih, Sri Martuti, Muhilal, and Joseph GAJ Hautvast

ABSTRACT The objectives of this study were to quantify the effectiveness of dietary retinol sources, orange fruit, and dark-green, leafy vegetables in improving vitamin A status, and to test whether orange fruit is a better source of vitamin A and carotenoids than are leafy vegetables. Anemic schoolchildren aged 7–11 y (n = 238) in West Java, Indonesia, were randomly allocated to 1 of 4 groups to consume 2 complete meals/d, 6 d/wk, for 9 wk: *1*) 556 retinol equivalents (RE)/d from retinol-rich food (n = 48); *2*) 509 RE/d from fruit (n = 49); *3*) 684 RE/d from dark-green, leafy vegetables and carrots (n = 45); and *4*) 44 RE/d from low-retinol, low-carotene food (n = 46). Mean changes in serum retinol concentrations of the retinol-rich, fruit, vegetable, and low-retinol, low-carotene groups were 0.23 (95% CI: 0.18, 0.28), 0.12 (0.06, 0.18), 0.07 (0.03,0.11), and 0.00 (−0.06, 0.05) μmol/L, respectively. Mean changes in serum β-carotene concentrations in the vegetable and fruit groups were 0.14 (0.12, 0.17) and 0.52 (0.43, 0.60) μmol/L, respectively. Until now, it has been assumed that 6 μg dietary β-carotene is equivalent to 1 RE. On the basis of this study, however, the equivalent of 1 RE would be 12 μg β-carotene (95% CI: 6 μg, 29 μg) for fruit and 26 μg β-carotene (95% CI: 13 μg, 76 μg) for leafy vegetables and carrots. Thus, the apparent mean vitamin A activity of carotenoids in fruit and in leafy vegetables and carrots was 50% (95% CI: 21%, 100%) and 23% (95% CI: 8%, 46%) of that assumed, respectively. This has important implications for choosing strategies for controlling vitamin A deficiency. Research should be directed toward ways of improving bioavailability and bioconversion of dietary carotenoids, focusing on factors such as intestinal parasites, absorption inhibitors, and food matrixes. *Am J Clin Nutr* 1998;68:1058–67.

KEY WORDS Vitamin A, carotenoids, bioavailability, fruit, vegetables, food-based strategies, schoolchildren, fortified food, parasitic infestation, children, Indonesia

INTRODUCTION

In populations in which vitamin A deficiency is a problem, consumption of fruit and vegetables is promoted because of their content of provitamin A carotenoids. The human body can convert these provitamin A carotenoids into the active form of vitamin A, retinol and its derivatives. In Western societies, fruit and vegetable consumption is promoted because of the association between their increased consumption and reduced risks of cancer and cardiovascular disease (1). This has been attributed to their content of antioxidants, such as carotenoids, flavonoids, and vitamins C and E.

The benefit of a higher intake of carotenoids from fruit and vegetables depends on the uptake of these molecules, which has been shown to vary widely among foods as well as among individuals (2). Studies in Western populations have found that the bioavailability of carotenoids was lower than expected from vegetables such as carrots and broccoli (2, 3). [Bioavailability is the fraction of an ingested nutrient that is available for utilization in normal physiologic functions or for storage (4)]. Most often, serum concentrations have been used to indicate the proportion of carotenoids that become available to the body. Therefore, the definition of carotene bioavailability that is used in this paper encompasses the freeing of carotenoids from food, their absorption, and their subsequent circulation in serum. However, when possible, more specific terminology is used to describe specific steps of the process. In our recent study of breast-feeding women in Indonesia, we found no improvement in serum concentrations of β-carotene and retinol after they consumed dark-green, leafy vegetables and carrots. However, there was a marked increase in both indexes after they consumed a wafer enriched with the same amount of β-carotene as in the vegetables (5).

The study reported in this paper was designed to test the hypothesis that carotenoids are more bioavailable from fruit than from leafy vegetables and carrots. The assumptions underlying this hypothesis were that carotenoids can be more easily freed from their matrix in fruit than from their matrix in leafy vegetables and carrots, and that the effect of inhibitors of carotene absorption present in fruit is less than that of inhibitors present in leafy vegetables. Both of these factors could affect the proportion of carotenoids that become available for absorption. After absorp-

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tion, the carotenoids could either increase serum carotene concentrations, or, in the case of provitamin A carotenoids, be converted to and increase serum concentrations of retinol.

To quantify the effectiveness of fruit and vegetables in improving vitamin A status, the increase in serum retinol concentrations after consumption of fruit and vegetables was compared both with that obtained after consumption of retinol-rich food which, according to current assumptions, contains similar amounts of vitamin A, as well as with that obtained after consumption of foods with a low vitamin A content. (Although the term "effectiveness" is used, "efficacy" may have been more appropriate. Such a distinction is common in drug intervention studies, but has not been used previously in dietary intervention studies. "Efficacy" refers to the effect when compliance is maximal, whereas "effectiveness" refers to the effect under conditions when compliance depends on program performance.) Also, throughout this article, food rich in preformed vitamin A is referred to as "retinol-rich food." Note, however, that preformed vitamin A in food occurs in the form of retinyl esters. Anemic schoolchildren in West Java were randomly allocated to 1 of 4 treatment groups to receive meals containing *1*) 650 retinol equivalents (RE) from dark-green, leafy vegetables and carrots (vegetable group); *2*) 650 RE from orange fruit (fruit group); *3*) 650 RE from retinol-rich food (retinol-rich group), or *4*) <70 RE from all sources (low-retinol, low-carotene group). Two meals were provided each day at school, 6 d/wk, for 9 wk.

SUBJECTS AND METHODS

Subjects

The study was conducted from July to October 1995. Children aged 7–11 y were selected from 10 schools in 3 neighboring villages in Bogor District, West Java, Indonesia. Schoolchildren usually eat 1–3 meals/d at home, which consist of rice with side dishes such as chili sauce, salted fish, and vegetables and receive pocket money (US$0.05–0.10) to buy snacks from vendors near school. Children eat fruit once or twice per month.

The purpose and procedures of the study were explained to parents or caretakers of children in grades 3–5. Almost all parents allowed their children to participate and signed an informed consent form. As in our previous study (5), we selected anemic subjects because serum retinol concentrations are correlated with hemoglobin concentrations (6). Thus, children (n = 1231) were screened initially on the basis of their hemoglobin concentration (Hemocue, Angelholm, Sweden) and hematocrit value, determined from a finger-prick blood sample.

Sample size requirements were calculated by using data from our previous study of breast-feeding women (5). To detect a difference in change in serum retinol concentration of 0.30 or 0.20 μmol/L between groups, with a power of 0.90 and an α value of 0.05, groups of 28 or 61 persons were required, respectively. Because we expected a difference smaller than the 0.34 μmol/L found in our previous study, we decided to enroll 60 children per group, assuming that data on 50 children would be available for analysis. Children with a hemoglobin concentration <110 g/L or a hematocrit value <0.36 at screening were invited to participate in the baseline data collection phase. They were, together with their parents or caretakers, informed about the study in more detail, given their first home assignment (ie, to record what they ate each day), and assigned to a treatment group. The selection criteria for enrollment in the intervention study were applied to the venous blood sample drawn at baseline. The criteria were a hemoglobin concentration <120 g/L and a hematocrit value <0.37, or when hemoglobin and hematocrit values did not correspond, ie, when one indicated anemia and the other did not, either a hemoglobin concentration <115 g/L or a hematocrit value <0.36. A total of 354 children were invited to participate in the baseline data collection phase, 338 of whom participated and 238 of whom met the selection criteria. The study was approved by the Medical Ethics Committee of the Ministry of Health, Indonesia, and by the Indonesian Institute of Science.

Design

Treatment groups

At each school, assignment to the 4 color-coded treatment groups was done randomly. Each child received 2 meals/d, 6 d/wk, for 9 wk. Meals contained vegetables, fruit, a protein source, and rice or rice noodles. The difference between the meals provided to the 4 groups was in the amount and source of vitamin A. The vegetable group (green) received carotene-rich, dark-green, leafy vegetables and carrots; the fruit group (purple) received carotene-rich fruit; the retinol-rich group (red) received retinol-rich protein sources; and the low-retinol, low-carotene group (white) received food low in both retinol and carotene. To ensure that all groups received a complete meal, food with a high vitamin A content was replaced by food with a low vitamin A content. For example, the vegetable group received carotene-rich vegetables, low-carotene fruit, and low-retinol protein sources. The main ingredients in the vegetable, fruit, and protein-source dishes with high or low vitamin A contents are shown in **Table 1**. The size of the side dishes was fixed, whereas the amount of rice was variable. Duplicate samples of the meals, without rice, were collected at breakfast during 4 nonconsecutive weeks, each week at a different school. The groups had been given color codes to avoid confusion about which dishes should be provided to which groups. Items such as plates, homework books, and cards to record consumption were all color coded appropriately.

Data collection

On the day before consumption of the first meals, children were examined clinically, a blood sample was drawn, food-consumption data were collected, and anthropometric measurements were made. During the intervention period, collection of food-consumption data continued weekly and stools were analyzed for protozoan cysts and worm eggs. On the day after consumption of the last meal, 9 wk into the intervention, children were again examined clinically, blood was collected, and anthropometric measurements were made. On this day, the children also received a large oral dose of vitamin A (200000 IU) and, if necessary, deworming medication, iron pills, or both.

Meal preparation and food consumption

In each school, meals were prepared by 4–6 village health volunteers supervised by graduates in Community Nutrition from Bogor Agricultural University. Recipes were provided to the volunteers weekly. The recipes listed, for each ingredient, the amount to be purchased and the cleaned amount to be cooked. For example, if the vegetable group of a school had 4 subjects, the recipe stated that 1 kg spinach should be bought and that 560 g cleaned spinach (4 × 140 g) should be cooked. After preparation of the dishes in the early morning, they were divided into 2 equal portions: 1 for breakfast and 1 for lunch. At school, each dish was divided equally among the

TABLE 1
Ingredients of dishes with a high or low vitamin A content

	High vitamin A[1]	Low vitamin A
Vegetables	Cassava leaves (*Manihot esculenta*): 70 g, 1 d; water spinach (*Ipomoea aquatica*): 150 g, 1 d; spinach (*Amaranthus tricolor/A. dubious/A. cruentus*): 140 g, 1 d; star gooseberry/"katuk" (*Sauropus androgynus*): 50 g, 1 d; and carrots (*Daucus carota*): 40 g, 2 d	Chinese cabbage (*Brassica rapa* cv. group Chinese cabbage), cucumber (*Cucumis sativus*); mungbean sprouts (*Vigna radiata*), white cabbage (*Brassica oleracea* cv. group white headed cabbage); potatoes (*Solanum tuberosum*), yard-long beans (*Vigna unguiculata* cv. group Sesquipedalis); and French beans (*Phaseolus vulgaris*)
Fruit	Papaya (*Carica papaya*): 320 g, 3 d; mango (*Mangifera indica*): 360 g, 2 d; and squash pumpkin (*Cucurbita moschata*): 200 g, 1 d	Apple (*Malus* spp); pineapple (*Ananas comosus*); banana (*Musa*); and jambu ayer (*Syzygium aqueum*)
Protein sources	1 egg and fortified margarine: 7 g, 2 d; chicken liver: 35 g, 2 d; and fortified chocolate milk: 2 glasses, 2 d	Salted fish, peanuts, tofu, shrimp, tempeh, chicken (once every 2 wk), fresh fish (no liver), and meatballs

[1] The amount prepared per child per day and the number of days per week the ingredient was provided are given.

plates of the appropriate color. Breakfast was served at ≈0700 and lunch between 1000 and 1300. Fruit was consumed after the rest of the meal had been eaten. The village health volunteers provided the meals, supervised consumption, and kept a record of attendance and leftovers. Once per week, the children were interviewed about what food and drinks they had consumed during the previous day other than those provided in the study (24-h recall). To help them remember, they had to record all food eaten daily. They did not know in advance when they would be interviewed.

Methods

Blood and serum collection

Between 0830 and 1100, venous blood samples (5 mL) were drawn from an antecubital vein of nonfasted subjects. Immediately after collection, part of the sample was removed to determine the hemoglobin concentration by the cyanomethemoglobin method, to measure hematocrit, and to count white blood cells. The remaining blood was placed on ice, protected from light, and, within a few hours centrifuged (750 × *g* for 10 min at room temperature) at the laboratory of the Nutrition Research and Development Centre (NRDC) in Bogor. Serum was frozen in a series of containers. One container was stored at −20°C for ≈4 mo until analyzed for albumin (bromocrescol green method) at the NRDC laboratory. The other containers were frozen at −20°C for 1 mo before being transferred, packed in dry ice, to Wageningen. The samples were then stored for 3–6 mo at −80°C until analyzed for retinol, carotenoids, ferritin, and transferrin receptor. Retinol and carotenoids were analyzed (5, 7) at the Division of Human Nutrition and Epidemiology, Wageningen Agricultural University. Ferritin (radioimmunoassay from Ciba Corning, Medfield, MA) and transferrin receptor (8) were analyzed by the University Hospital of Liege, Belgium.

Anthropometry

Weight, with subjects wearing light clothing, was measured to the nearest 0.1 kg with a digital electronic scale (770 alpha; Seca, Hamburg, Germany) and height was measured to the nearest 0.1 cm with a microtoise.

Feces examination

Stool samples were examined for the presence of worm eggs and protozoan cysts with the Ridley method and the load of worm eggs was quantified by using the Kato-Katz method (9).

Duplicate portion analysis

Duplicate samples of the meals were pooled per treatment group and per week (or per 3 d) and were packed in dry ice for transport to the laboratory at Wageningen Agricultural University, where they were analyzed for fat, protein, dietary fiber, iron, retinol, and carotenoids (10–12). For analysis of retinol and carotenoids, samples were homogenized and extracted with tetrahydrofuran, and the volume of the solvent was reduced. The residue was saponified overnight with 5% methanolic KOH at room temperature and split in dichloromethane and water. The dichloromethane layer was washed with water until a pH < 9 was reached and was then evaporated. The residue was dissolved in methanol:tetrahydrofuran (75:25, by vol) and injected onto the HPLC column. The carbohydrate content was calculated by difference. Results were averaged per treatment group.

Nutrient intake

Nutrient intake, other than from the meals provided, was calculated from the 24-h recall data by using Indonesian food-composition tables (13–15), except for the content of dietary fiber in rice (16) and for carotenoids. The carotene content was taken from analyses in Wageningen (12) and from a table with the most recent data on the carotene content of food in developing countries (17). The carotene content of milk, eggs, and poultry was assumed to be 30% of the total vitamin A content and of fish, liver, and animal fat to be 10% of the total vitamin A content (18). Food-composition data were entered into a computerized database (VBSedit, version 1.0; B-ware Nutrition Software, Wageningen, Netherlands, 1995). Nutrient intake was calculated by using the computer program KOMEET (version 2.0c; B-ware Nutrition Software).

Estimating apparent conversion factors

The apparent conversion factor (x) for calculating the amount of retinol equivalents provided by provitamin A carotenoids from fruit or vegetables was estimated by using the following formula:

Change in serum retinol concentration of retinol-rich group/ μg retinol + (μg carotene/x) provided to retinol-rich group = change in serum retinol concentration of fruit or vegetable group/ μg retinol + (μg carotene/x) provided to fruit or vegetable group (*1*)

where μg carotene = μg *all-trans*-β-carotene + 0.5 × μg α-carotene + 0.5 × μg β-cryptoxanthin + 0.5 × μg *cis*-isomers of β-carotene. The upper and lower limits of the 95% CI for the apparent conversion factor (x) were estimated by using the limits of the 95% CIs for the changes in serum retinol concentration of the respective treatment groups.

Statistical methods

Data for variables of which the histogram of observations showed a normal distribution are reported as means ± SDs; those with a non-normal distribution are reported as medians and 25th–75th percentiles. Changes in biochemical indicators were calculated by subtracting the value before the intervention from the value after the intervention. Those changes had a normal distribution; therefore, data are presented as means and 95% CIs. Changes within groups were examined with a paired t test. Differences between groups were examined by analysis of variance (ANOVA) or, for indexes with a non-normal distribution, by the Kruskal-Wallis test. Multiple regression analysis was used to compare changes in indicators between groups by using dummy variables for treatment and controlling for variables such as baseline level of the indicator, weight change, and parasitic infestation.

Nutrient intake during the intervention, other than from the food provided, was calculated from the median intake of each child, which was calculated from data collected on 9 (n = 165) or 10 (n = 23) d during the intervention. Wilcoxon's matched-pairs signed-ranks test was used to examine changes in intake within groups. The computer package SPSS 4.01 (SPSS Inc, Chicago) was used for all statistical calculations and a P value <0.05 was considered significant.

RESULTS

Of the 238 children enrolled, 231 completed the study. Blood was drawn only on days on which a child did not manifest clinical signs of infection. Analysis of pooled data from baseline and follow-up (n = 461) showed no correlation between white blood cell counts and serum retinol concentrations (r = −0.05, P = 0.27) nor with the natural logarithm of serum ferritin concentrations (r = 0.09, P = 0.06). However, white blood cell counts >9600 × 10^9/L (n = 46) correlated with serum retinol concentrations (r = −0.29, P < 0.05) as well as with the natural logarithm of serum ferritin concentrations (r = −0.35, P < 0.05). Therefore, only the data of children with white blood cell counts <9600 × 10^9/L at baseline as well as at follow-up (n = 188) were analyzed.

This reduction in size of the study population resulted in a power to detect the observed differences, and the observed variances, between the vegetable group and the retinol-rich and low-retinol, low-carotene groups of 0.99 and 0.79, respectively, and between the fruit group and the retinol-rich and low-retinol, low-carotene groups of 0.78 and 0.89, respectively. To detect a significant difference with a power of 0.90 between the fruit and the vegetable groups, ≥258 subjects should have been studied. In general, the power to detect differences in changes of serum carotene concentrations among relevant groups was higher than for serum retinol concentrations. There were no significant differences between treatment groups in any of the characteristics shown in **Table 2**.

Food consumption and nutrient intake

The children were given 2 meals/d for 51 d (6 d/wk for 9 wk, except for 3 d, which were holidays). Records of attendance and of leftovers showed that, across all treatment groups, 90% of the vegetables, 94% of the fruit, and 90% of the protein-rich food provided had been consumed. The mean (95% CI) proportion of vegetables consumed by the vegetable group, 86% (82%, 94%), was significantly less than the proportion of fruit consumed by the fruit group, 92% (88%, 96%), and the proportion of retinol-rich protein-sources consumed by the retinol-rich group, 94% (90%, 96%). However, because these differences were very small compared with the variation in vitamin A content of the food, these consumption data were not used in further analyses.

TABLE 2
Basic characteristics by treatment group

	Treatment group			
	Vegetable (n = 45)	Fruit (n = 49)	Retinol-rich (n = 48)	Low-retinol, low-carotene (n = 46)
Boys	25	29	23	27
Girls	20	20	25	19
Age (y)	10.5 ± 1.3[1]	10.6 ± 1.1	10.1 ± 1.1	10.2 ± 1.3
Weight (kg)	24.3 ± 4.4	23.4 ± 3.2	23.4 ± 2.8	23.6 ± 4.2
Height (cm)	124.9 ± 8.1	124.3 ± 6.9	124.8 ± 6.0	124.2 ± 6.5
Parasitic infestation (% with positive stool)[2]				
Ascaris lumbricoides	62	59	53	48
Trichuris trichuria	78	82	79	78
Entamoeba histolytica	16	22	4	15
Giardia intestinalis	4	0	0	4
Hookworm	0	0	0	0
No infection (%)	11	6	8	13
Egg load (epg)[3]				
Ascaris lumbricoides	4420 (360–14670)	2640 (380–14680)	4320 (800–15940)	6220 (460–26340)
Trichuris trichuria	160 (80–400)	360 (130–1030)	200 (100–660)	180 (80–390)

[1] $\bar{x}$ ± SD.
[2] In the retinol-rich group, stools from 47 children were tested.
[3] Eggs per gram feces for those with the infection, median (25th–75th percentile).

The carotene and retinol contents of the food provided are shown in **Table 3**. Subjects in the vegetable group received about one-fourth more vitamin A per day than did those in the fruit and retinol-rich groups. The dietary fiber content was higher in the meals provided to the vegetable and fruit groups (14 g) than in the meals provided to the retinol-rich and low-retinol, low-carotene groups (11 g) (data not shown). The total daily intakes of nutrients during the intervention, ie, intake of food provided and of food not provided by us, are shown in **Table 4**. In each group, vitamin A intake was ≈100 RE higher than that provided by the meals. The intake of fat, protein, and iron was highest in the vegetable group. Intake of vitamin C was highest in the fruit group. Vitamin C intake in the vegetable group was probably overestimated because it was based on the content of raw vegetables as reported in food-composition tables (13–15).

Changes in serum retinol concentrations

Serum concentrations of retinol and carotenoids at baseline are shown in **Table 5**. There were no significant differences among groups. Correlations between serum concentrations of retinol and individual carotenoids were 0.31 for β-carotene, 0.23 for β-cryptoxanthin, 0.20 for lutein, 0.18 for lycopene, 0.18 for zeaxanthin, and 0.16 for α-carotene. The serum retinol concentration (μmol/L) increased significantly in all groups, except in the low-retinol, low-carotene group ($\bar{x}$: 0.00; 95% CI: −0.06, 0.05) (**Figure 1**). The increase was larger in the retinol-rich group (0.23; 0.18, 0.28) than in the fruit (0.12; 0.06, 0.18) and vegetable (0.07; 0.03, 0.11) groups. Multiple regression analysis, with baseline serum retinol concentration and weight change controlled for, did not alter these findings (data not shown). The change in serum retinol concentrations was not correlated with baseline serum β-carotene concentrations in either the vegetable or the fruit group.

Estimation of apparent conversion factors

To estimate apparent conversion factors, we used changes in serum retinol concentrations, as calculated above, because in the low-retinol, low-carotene group the concentration had not changed; we used the amount of retinol and carotene provided because the intake of food other than that provided by us was relatively small, almost the same in all groups, and its composition was less precisely known. With use of equation *1* given above, the mean apparent factor for converting β-carotene into retinol equivalents was estimated to be 26 (95% CI: 13, 76) for vegetables and 12 (95% CI: 6, 29) for fruit.

Effect of parasitic infestation

Because ≈60% of the children were infested with *Ascaris*, changes in serum retinol concentrations were correlated with *Ascaris* infection. There was a significant correlation between the natural logarithm of egg count and change in serum retinol concentrations in the fruit group ($r = -0.31$, $P < 0.05$), but not in the other 3 groups. In addition, there was no relation between change in serum β-carotene concentrations and *Ascaris* infection in any of the groups.

Changes in serum carotene concentrations

Changes in serum carotene concentrations are shown in **Table 6**. The increase in serum β-carotene concentrations compared with the amount of β-carotene provided was 5–6 times higher in the fruit group than in the vegetable group: change in serum concentration (μmol/L)/amount provided (mg/d) = 0.52/2.3 compared with 0.14/3.5. In the vegetable group, the increase in serum carotene compared with the amount of carotene provided was higher for lutein than for β-carotene. In the fruit group, the increase in serum carotene compared with the amount of carotene provided was highest for β-cryptoxanthin, lower for β-carotene, and lowest for lycopene.

Hematologic indicators and anthropometric indexes

Baseline concentrations and changes in hematologic indicators are shown in **Table 7**. The baseline values were not different among the groups. The hemoglobin concentration increased significantly in all groups, except in the vegetable group. The change in the vegetable group was significantly lower than in the fruit and retinol-rich groups. The hematocrit value increased significantly in all groups. Changes in serum ferritin concentrations were not significant and were not different among the groups. The fall in serum transferrin receptor concentration was significant only in the low-carotene, low-retinol group and was significantly different from the retinol-rich group, but not from either the vegetable or the fruit group.

TABLE 3
Carotenoids, retinol, and vitamin A provided by the meals per treatment group per day[1]

	Treatment group			
	Vegetable	Fruit	Retinol-rich	Low-retinol, low-carotene
Retinol (mg/d)	—	—	0.5 (0.3–0.8)	—
all-trans-β-Carotene (mg/d)	3.5 (2.1–4.4)	2.3 (1.2–2.9)	0.2 (0.1–0.2)	0.2 (0.2)
cis-β-Carotene (mg/d)	0.6 (0.4–0.8)	0.3 (0.2–0.5)	<0.1	<0.1
α-Carotene (mg/d)	0.5 (0.3–0.7)	0.3 (0–0.6)	0.1 (0.1)	0.1 (0.1)
β-Cryptoxanthin (mg/d)	0.1 (0–0.1)	1.3 (1.2–1.4)	<0.1	<0.1
Lutein (mg/d)	5.9 (3.8–8.2)	0.8 (0.5–1.1)	0.2 (0.2)	0.2 (0.2)
Zeaxanthin (mg/d)	1.2 (0.8–1.6)	0.2 (0.2–0.3)	0.2 (0.1–0.2)	0.1 (0.1)
Lycopene (mg/d)	0.2 (0.1–0.8)	4.8 (4.4–4.9)	0.1 (0–0.4)	0.1 (0–0.1)
Vitamin A (RE/d)				
From retinol	—	—	512 (338–827)	—
From carotenoids[2]	684 (414–862)	535 (307–686)	44 (32–55)	44 (36–49)

[1] Values are the mean of the 4 pooled week samples, with the lowest and the highest week values in parentheses. The retinol and carotene contents were analyzed from duplicate, prepared, complete meals, except rice, collected at breakfast. For each treatment group, meals were collected during 4, nonconsecutive weeks, each week at a different school. Before analysis, meals were pooled per treatment group per week.

[2] Retinol equivalents (RE) calculated by dividing the amount (μg) of *all-trans*-β-carotene by 6 and of other provitamin A carotenoids, including *cis*-isomers of β-carotene, by 12.

TABLE 4
Total daily intake of nutrients during the intervention, including foods provided in the treatment groups[1]

	Treatment group			
	Vegetable (n = 45)	Fruit (n = 49)	Retinol-rich (n = 48)	Low-retinol, low-carotene (n = 46)
Energy (MJ)	7.2 (6.7–8.1)	7.2 (6.6–7.8)	7.1 (6.4–8.0)	7.3 (6.6–7.8)
Fat (g)	39 (33–46)[b]	30 (26–37)[a]	34 (25–37)[a]	30 (26–36)[a]
Protein (g)	43 (39–50)[b]	38 (34–42)[a]	37 (33–46)[a]	38 (36–45)[a]
Carbohydrate (g)	291 (276–331)	304 (283–334)	304 (268–330)	308 (284–345)
Retinol (RE)	13 (2–32)[a]	5 (0–13)[a]	522 (514–533)[b]	12 (2–21)[a]
Carotenoids (RE)[2]	743 (710–804)[c]	604 (567–655)[b]	110 (85–177)[a]	100 (65–133)[a]
Total vitamin A (RE)[2]	769 (734–867)[d]	631 (583–686)[b]	660 (621–708)[c]	140 (87–179)[a]
Iron (mg)	15 (13–17)[b]	12 (11–14)[a]	13 (11–15)[a]	13 (11–16)[a]
Vitamin C (g)	110 (108–118)[b]	184 (181–189)[c]	34 (31–38)[a]	34 (31–37)[a]

[1] Median; 25th–75th percentiles in parentheses, as calculated by adding the individual median intake of nutrients from foods not provided by the study (calculated from 24-h recall on 9 or 10 d) to the analyzed composition of the meals provided. Rice intake was variable. An estimate of 200 g rice per meal was used for these calculations. The nutrient content of the rice provided and of the foods not provided in the study, as well as the vitamin C intake from all foods consumed, were derived from food-composition tables. Values within a row with different superscript letters are significantly different, $P < 0.05$ (Kruskal-Wallis test, followed by the Mann-Whitney U test).

[2] Retinol equivalents (RE) calculated by dividing the amount (μg) of *all-trans*-β-carotene by 6 and of other provitamin A carotenoids, including *cis*-isomers of β-carotene, by 12.

The increases in body weight were not significantly different between the 4 groups (0.6–0.8 kg). The height increment was larger in the fruit group ($\bar{x}$: 2.2 cm; 95% CI: 1.8, 2.5) than in the low-retinol, low-carotene group (1.6 cm; 1.3, 2.0). Height increments in the vegetable and retinol-rich group were 1.8 (1.5, 2.1) and 1.9 (1.5, 2.3) cm, respectively.

DISCUSSION

This study indicated that in anemic children with a marginal vitamin A status, the mean apparent effectiveness of fruit in improving vitamin A status was 50% (95% CI: 21%, 100%), and of dark-green, leafy vegetables and carrots was 23% (8%, 46%), of what has been assumed up until now. The current assumption is that 6 μg dietary β-carotene provides 1 RE. According to our results, a better estimate would be that 1 RE is provided by 12 μg (95% CI: 6 μg, 29 μg) β-carotene from fruit, and by 26 μg (13 μg, 76 μg) β-carotene from dark-green, leafy vegetables and carrots. The study design and the assumptions underlying the estimation of apparent conversion factors need careful examination.

Choice of study population

The study was carried out in a population with a marginal vitamin A status to enable detection of changes in vitamin A status. By selecting children with anemia, we managed to select a population with an average serum retinol concentration of 0.71 μmol/L. This is comparable with concentrations found in a national survey in Indonesia of children aged <5 y (19). However, the serum retinol concentration of schoolchildren in general is expected to be slightly higher than that of our study population because we only studied anemic children.

Choice of study design

Because a dietary intervention cannot be carried out in a double-masked manner, compliance with treatment was ensured in another way. At each school, the children were randomly allocated to treatment group and meals were consumed under supervision. The children were given 3 times the normal daily vitamin A intake in the form of food that was not consumed very often and never in a large quantity, such as liver, milk, and orange fruit. This made it de facto impossible for the children to compensate their vitamin A intake by food consumption outside our control. This was confirmed by the data on nutrient intake. The proportion of the food provided that was consumed by the various groups was similar. The negative control group (low-retinol, low-carotene group) differed from the other groups only in the amount of retinol and carotene provided. Thus, the design was appropriate for comparing the effectiveness in improving vita-

TABLE 5
Serum concentrations of retinol and carotenoids at baseline in the 4 treatment groups

	Treatment group			
	Vegetable (n = 45)	Fruit (n = 49)	Retinol-rich (n = 48)	Low-retinol, low-carotene (n = 46)
Retinol (μmol/L)	0.73 ± 0.17[1]	0.71 ± 0.24	0.69 ± 0.17	0.70 ± 0.19
β-Carotene (μmol/L)	0.14 ± 0.06	0.15 ± 0.10	0.14 ± 0.06	0.14 ± 0.06
β-Cryptoxanthin (μmol/L)	0.12 (0.07–0.19)[2]	0.13 (0.06–0.23)	0.11 (0.07–0.19)	0.10 (0.05–0.19)
α-Carotene (μmol/L)	0.06 ± 0.04	0.05 ± 0.04	0.06 ± 0.04	0.05 ± 0.03
Lutein (μmol/L)	0.32 ± 0.14	0.35 ± 0.14	0.35 ± 0.16	0.34 ± 0.15
Lycopene (μmol/L)	0.04 (0.02–0.09)	0.04 (0.02–0.07)	0.03 (0.01–0.05)	0.04 (0.02–0.10)
Zeaxanthin (μmol/L)	0.10 ± 0.10	0.10 ± 0.05	0.08 ± 0.05	0.09 ± 0.06

[1] $\bar{x}$ ± SD. There were no significant differences among groups.

[2] Median; 25th–75th percentiles in parentheses.

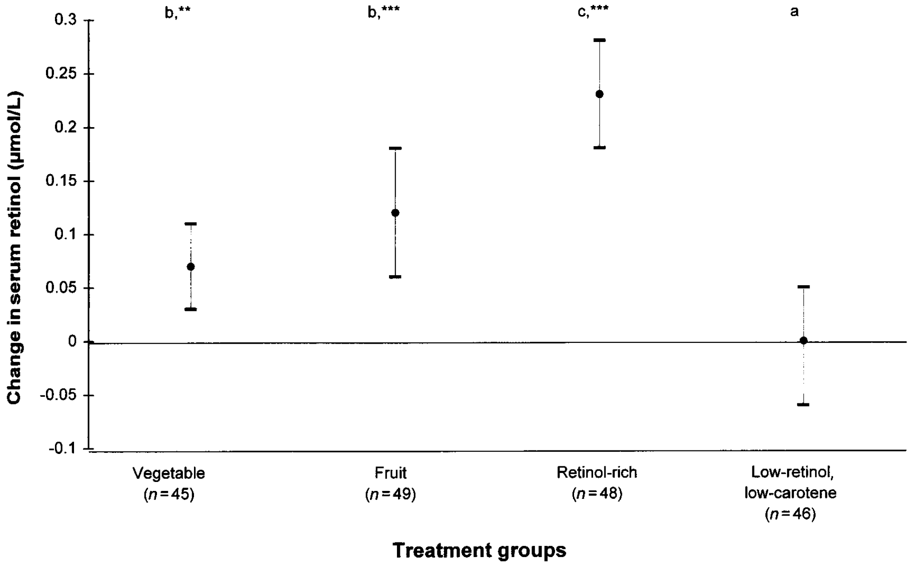

FIGURE 1. Mean changes (and 95% CIs) in serum retinol concentrations by treatment group. Groups with different letters are significantly different, $P < 0.05$ (ANOVA, post hoc test of least significant differences). Significant change: $^{**}P < 0.01$, $^{***}P < 0.001$.

min A status of provitamin A and retinol provided as vegetables, fruit, or retinol-rich food.

Estimation of apparent conversion factors

The way that we chose to estimate the apparent conversion factors is similar to the way that the currently used conversion factors were derived. Both methods are based on changes in serum retinol concentration in humans after consumption of carotene-rich food. The serum retinol concentration is the result of absorption of provitamin A carotenoids, their conversion to retinol, and the subsequent distribution, storage, metabolism, and clearance of retinol. Each of these aspects is affected by several factors. It is almost impossible to control all these factors when estimating conversion factors. However, for designing and evaluating food-based programs to combat vitamin A deficiency, an estimate of conversion factors is needed urgently. Therefore, we have made a quantitative estimate of so-called apparent conversion factors, but it is important to realize the limitations as well as the magnitude of their ranges.

Four of our assumptions to estimate the apparent conversion factors need to be discussed. The first assumption was that when the amount of retinol equivalents derived from different diets was the same, changes in serum retinol concentration would be the same. If some retinol was stored in the liver, it would mainly have occurred in the group with the largest increase in serum retinol concentration, the retinol-rich group. Logically, in that

TABLE 6
Changes in serum concentrations of carotenoids over the course of the intervention in the 4 treatment groups[1]

	Treatment group			
	Vegetable (n = 45)	Fruit (n = 49)	Retinol-rich (n = 48)	Low-retinol, low-carotene (n = 46)
β-Carotene (μmol/L)	0.14[b]	0.52[c]	0.06[a]	0.03[a]
	(0.12, 0.17)[2]	(0.43, 0.60)[2]	(0.04, 0.09)[2]	(0.01, 0.05)[3]
β-Cryptoxanthin (μmol/L)	0.00[a]	0.96[b]	0.00[a]	0.00[a]
	(−0.03, 0.04)	(0.80, 1.12)[2]	(−0.04, 0.05)	(−0.04, 0.05)
α-Carotene (μmol/L)	0.05[b,c]	0.05[c,d]	0.04[a,b]	0.03[a]
	(0.03, 0.06)[2]	(0.04, 0.06)[2]	(0.03, 0.05)[2]	(0.02, 0.03)[2]
Lutein (μmol/L)	0.31[b]	0.07[a]	0.07[a]	0.04[a]
	(0.23, 0.38)[2]	(0.02, 0.11)[3]	(0.04, 0.10)[2]	(0.00, 0.07)[4]
Lycopene (μmol/L)	0.01[a]	0.25[b]	0.02[a]	0.02[a]
	(−0.01, 0.03)	(0.20, 0.31)[2]	(−0.02, 0.05)	(−0.01, 0.04)
Zeaxanthin (μmol/L)	0.00[a]	0.02[a,b]	0.04[b]	0.00[a]
	(−0.03, 0.03)	(0.01, 0.04)[3]	(0.02, 0.05)[2]	(−0.02, 0.02)

[1] Mean; 95% CI in parentheses. Means within a row with different superscript letters are significantly different, $P < 0.05$ (ANOVA).
[2–4] Significant change: $^{2}P < 0.001$, $^{3}P < 0.01$, $^{4}P < 0.05$.

TABLE 7
Baseline concentrations and changes in hematologic indicators in the 4 treatment groups

	Treatment group			
	Vegetable (n = 45)	Fruit (n = 49)	Retinol-rich (n = 48)	Low-retinol, low-carotene (n = 45–46)
Hemoglobin (g/L)				
Initial[1]	111 ± 7	111 ± 10	111 ± 9	112 ± 10
Change[2]	1[a]	5[b]	5[b]	4[a,b]
	[−1, 3]	[2, 8][3]	[3, 8][4]	[1, 6][5]
Hematocrit				
Initial[1]	0.34 ± 0.02	0.34 ± 0.02	0.34 ± 0.02	0.33 ± 0.02
Change[2]	0.02	0.02	0.03	0.03
	[0.01, 0.03][4]	[0.02, 0.03][4]	[0.02, 0.03][4]	[0.02, 0.04][4]
Serum ferritin (μg/L)				
Initial[6]	3.2 (1.6–4.4)	3.8 (2.4–5.5)	3.6 (2.4–4.7)	3.2 (2.0–4.8)
Change[2]	−0.2	−0.2	0.1	−0.3
	[−0.7, 0.3]	[−0.9, 0.5]	[−0.9, 1.0]	[−0.7, 0.1]
Serum transferrin receptor (mg/L)				
Initial[6]	4.2 (3.6–5.3)	4.4 (3.7–5.6)	4.2 (3.7–5.4)	4.7 (3.8–5.4)
Change[6]	−0.11[a,b]	−0.19[a,b]	0.06[a]	−0.31[b]
	[−0.27, 0.05]	[−0.38, 0.00]	[−0.12, 0.23]	[−0.61, −0.02][5]

[1] $\bar{x}$ ± SD. Values within a row with different superscript letters are significantly different, $P < 0.05$.
[2] Mean; 95% CI in brackets.
[3–5] Significant change: [3] $P < 0.01$, [4] $P < 0.001$, [5] $P < 0.05$.
[6] Median; 25th–75th percentile in parentheses.

case, our estimate of the apparent vitamin A activity of carotenoids from fruit and vegetables would be too high. The second assumption—that the carotenoids provided to the retinol-rich group had the same bioavailability as those given to the fruit or the vegetable group—was too pessimistic, but the carotene content of retinol-rich meals was very small. The third and fourth assumptions—that bioconversion of *all-trans*-β-carotene results in twice as much retinol as does the bioconversion of α-carotene, β-cryptoxanthin, and *cis*-isomers of β-carotene, but that their absorbabilities are the same—were more difficult to evaluate. This is not of much concern for dark-green, leafy vegetables, for which *all-trans*-β-carotene is the main provitamin A. For fruit, however, the situation is more complicated because the increase in the serum concentration in relation to the amount provided was 5 times higher for β-cryptoxanthin than for β-carotene. Others, however, have reported that absorption kinetics of β-carotene and β-cryptoxanthin are similar (20). Because information on the bioavailability and bioconversion of different provitamin A carotenoids and their isomers is limited, and because the current assumptions about retinol equivalents provided by different dietary carotenoids are also based on the assumption that their absorbabilities are the same (21), we regarded the third and fourth assumptions as valid.

Because carotenes can be cleaved not only in the intestinal mucosa but also in other tissues (22), it has been suggested that increased β-carotene intake can raise tissue retinol concentrations without raising concentrations of retinol and β-carotene in serum. In this case, serum retinol concentrations could not be used to estimate apparent conversion factors. However, this is an unlikely explanation for the results reported in this study. If serum concentrations of retinol and β-carotene increase after one source of provitamin A carotenoids is consumed, they should also increase after another source is consumed because the intestinal mucosa would be unable to distinguish between β-carotene of different origins.

Changes in serum carotene concentrations

Whereas fruit was approximately twice as effective at increasing serum retinol concentrations than were vegetables, the increase in serum β-carotene concentration in relation to the amount of β-carotene provided was 5–6 times higher for fruit than for vegetables. This difference can perhaps be attributed to the decrease in conversion efficiency at increased rates of β-carotene absorption (21).

This study showed not only that the bioavailability of carotenoids differs among foods, but also that it differs among carotenoids. The finding of a relatively higher bioavailability of lutein than of β-carotene from vegetables was also reported in other intervention studies that used food with a higher content of lutein than of β-carotene (4, 5, 23). This difference, as well as the difference observed between the carotenoids from fruit, may be explained by differences in polarity. Carotene bioavailability appears to increase as polarity increases (24).

Also, absorption of carotenoids may depend on the presence of other carotenoids. It has been found that if the lutein content is lower than that of β-carotene, its absorption is inhibited by β-carotene (4, 23). But the opposite, an inhibition of β-carotene absorption by lutein, has not been found in studies in which β-carotene was provided in diets containing various amounts of lutein (4, 23). Inhibition of the conversion of β-carotene to retinol by lutein has been found in in vitro studies (25) as well as in in vivo studies that used relatively large amounts of the purified form of these carotenoids (26). However, the present study indicated that its relative importance, for example when compared with the decrease in conversion efficiency when relatively large amounts of carotenoids are absorbed, may be limited because the bioconversion of β-carotene to retinol was more effective in the vegetable group than in the fruit group.

After consideration of all these interactions among carotenoids, the most likely explanation for the difference in bioavailability of β-carotene between fruit and vegetables was their different matrixes. More destructive methods are required for freeing β-carotene from chloroplasts within plant cells of dark-green, leafy vegetables than from chromoplasts of yellow and orange fruit where β-carotene is dissolved in oil droplets. In carrots, β-carotene is present as crystals, which dissolve very slowly. The subsequent incorporation of β-carotene into fat micelles for absorption may also be more difficult for β-carotene from vegetables than from fruit because of the nature of the dietary fiber (27, 28), which may result in more entrapment of β-carotene before it can be incorporated into micelles.

Comparison of this study with the previous study of breast-feeding women

Changes in serum retinol and carotenoid concentrations in the vegetable group of the present study were higher than those in the vegetable group of our previous study (5). For both the previous and the present study, the change in the control group was subtracted from the change in the vegetable group: 0.04 (not different from control group) and 0.07 μmol/L for retinol, 0.05 and 0.11 μmol/L for β-carotene, and 0.11 and 0.27 μmol/L for lutein, respectively. The amount of carotenoids provided was the same in both studies. Several factors might explain the larger increments in the children in the present study than in the women in the previous study (5): *1*) the children received the vegetables in 2 meals whereas the women received them in 1 meal; *2*) the intensity of *Ascaris* infestation was lower in the children [median: 4720 eggs per gram feces (epg); 25th–75th percentiles: 610–16990 epg] than in the women (13020 epg; 1580–40540 epg); and *3*) requirements for vitamin A intake are lower for children than for breast-feeding women because children are smaller and do not secrete vitamin A through breast milk.

Parasitic infestation

The effect of parasitic infestation was not assessed in this study because deworming was only done after the intervention, but the data were analyzed for the relation between intensity of *Ascaris* infection and changes in biochemical indexes. In the fruit group we found that when the infection intensity was high, the increase in serum retinol concentrations tended to be smaller. However, we did not find such a trend for serum retinol in the other 3 groups, nor for serum β-carotene in any of the groups. It was shown previously that absorption of retinol is relatively insensitive to parasitic infestation (29). The absence of a relation between parasitic infestation and changes in serum β-carotene in the vegetable group may indicate that, in this group, parasitic infestation had a relatively small effect on the already complicated process of freeing β-carotene from leafy vegetables. In the fruit group, it appeared that freeing and absorption of β-carotene were relatively undisturbed, but that its bioconversion was affected. Jalal (30) reported that deworming markedly increased serum retinol concentrations after consumption of red sweet potato when *Ascaris* infection was high but not when it was low. The interaction between parasitic infestation and bioavailability and bioconversion of carotenoids needs further study because parasitic infestations are highly prevalent in areas where vegetables and fruit are the main source of dietary vitamin A.

Factors affecting bioavailability and bioconversion of provitamin A carotenoids

The wide CIs of the estimated apparent conversion factors clearly illustrated that the bioavailability and bioconversion of provitamin A carotenoids are influenced by many factors (31) and also vary widely among individuals. From the results of the present and our previous study (5), it seems that the most important factors affecting bioavailability and bioconversion are the food matrix, parasitic infestation, and dietary fiber, which can inhibit absorption (27, 28). The food matrix and parasitic infestation may act independently as well as in combination with each other. Fat is essential for carotene absorption, but because the fat content was maximized in both studies, it cannot explain the fact that the apparent vitamin A activity found for fruit and vegetables in these 2 studies was lower than the activity assumed on the basis of currently recommended conversion factors for calculating retinol equivalents.

Biomarkers for fruit and vegetable intake

Because a higher intake of fruit and vegetables has been shown to be associated with lower risks of cancer and cardiovascular disease (1), there is a need for biomarkers of fruit and vegetable intakes. Our data showed that the bioavailability of carotenoids differ and that their bioavailability depends on the nature of the food ingested. Therefore, an adequate biomarker of fruit and vegetable intakes would be a mixture of carotenoids. In addition, these data showed that bioavailability is important when determining the possible contribution of food carotenoids to their antioxidant activity in humans.

Hematologic indicators and anthropometric indexes

We also assessed changes in hematologic indicators and in weight and height. The amount of heme iron was approximately the same in the 4 diets. Although the vegetable group received the largest amount of non-heme iron, subjects in the vegetable group had the smallest increase in hemoglobin concentration. This may have been due in part to the high content of phytate in dark-green, leafy vegetables, which inhibits iron absorption. These findings indicate that the bioavailability of carotenoids as well as that of iron from leafy vegetables is relatively poor. The relatively large amount of vitamin C in the fruit group (32) and the improvement in vitamin A status in the retinol-rich group (6) may have played a role in improving the hemoglobin concentration in these groups. Changes in the other hematologic indexes appeared to be so small that this study did not have the statistical power to detect differences in increments among the groups. The larger increment in height in the fruit group may have been due to the increase in serum carotene concentrations.

Conclusion

This study challenges the assumption that 6 μg dietary β-carotene provides 1 RE. The mean apparent effectiveness of fruit in improving vitamin A status was 50% (95% CI: 21%, 100%) whereas that of dark-green, leafy vegetables and carrots was 23% (8%, 46%) of that assumed previously. This has important implications for the choice of strategies for controlling vitamin A deficiency. The role of vitamin A capsules should not be underestimated and dietary diversification should, wherever possible, specifically aim at increasing the intake of vitamin A from fruit, animal food, and fortified food and at maximizing the bioavailability of carotenoids from dark-green, leafy vegetables. The large range of apparent effectiveness found for fruit (21–100%) and dark green, leafy vegetables (8–46%) in increasing serum retinol concentrations prompts research on ways of quantifying and improving the bioavailability and bioconversion of dietary carotenoids, focusing on the effect of factors such as intestinal parasite infestation, the food matrix, absorption inhibitors, and bioconversion inhibitors.

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Who has a high vitamin A intake from plant foods, but a low serum retinol concentration? Data from women in Indonesia

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Objective: To examine whether the relationship between vitamin A intake, from plant and animal foods, and vitamin A status is the same throughout a population.
Design: Analysis of cross-sectional data on vitamin A intake, vitamin A status, physiological condition and socio-economic status.
Setting: Central Java, Indonesia.
Subjects: Women with a child ≤ 24 months old ($n = 600$).
Results: Mean serum retinol concentration of women with animal vitamin A intake below or above the median (50 RE/d) was 1.28 and 1.38 μmol/L, respectively ($P < 0.05$). For those with intake above the median the distribution curve for serum retinol concentration was shifted towards the right, to higher concentrations. Serum retinol concentration of women with plant vitamin A intake below or above the median (279 RE/d) was 1.30 and 1.36 μmol/L, respectively ($P < 0.05$). Again, the distribution curve for serum retinol was shifted towards higher concentrations for women with an intake above the median, except for the subgroup of 25% with the lowest serum retinol concentration (< 1.10 μmol/L). These women did not seem to benefit from their relatively high vegetable intake. They also had the lowest socio-economic status.
Conclusions: The subgroup that was most in need of vitamin A could not obtain it from plant foods. It may well be that, because of their lower socio-economic status, their hygiene conditions were worse and therefore host-related factors that affect carotene bioavailability, such as parasitic infestation, were less favourable in this group. They depended on supplements and, if affordable, on animal foods, fruits and/or fortified products.
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Descriptors: vitamin A intake; humans; carotene bioavailability; parasitic infestation; Indonesia

Introduction

Recently, there has been renewed discussion about the effectiveness of vegetables for improving vitamin A status. The bioavailability of carotenoids from leafy vegetables, and to a lesser extent also from non-leafy vegetables and fruits, appears to be lower than previously assumed (Bulux *et al*, 1994; de Pee *et al*, 1995; 1998a; Micozzi *et al*, 1992). A recent study with schoolchildren found that the effectiveness for improving vitamin A status of vegetables (mean [95% CI]) was 23% [8–46%] and of fruits 50% [21–100%] of what has been assumed (de Pee *et al*, 1998a). Analysis of cross-sectional data from women in Central-Java confirmed that the effectiveness of vegetables was approximately 16–23% of what has been assumed (de Pee *et al*, 1998b).

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The effectiveness of vegetables for improving vitamin A status depends on the bioavailability and the bioconversion of their provitamin A carotenoids. Recently, the array of factors that influence carotene bioavailability and bioconversion have been summarised (de Pee & West, 1996). Some of these factors are intrinsic to the carotenoids and their food source, such as presence of inhibitors and enhancers of absorption, and food matrix, while other factors are related to the host, such as parasitic infestation and nutrient status. Within a population, the variation in food preparation and food consumption practices is limited. Therefore, the large range of responsiveness to dietary carotenoids within a population is more likely to be due to differences in host related factors, than to differences in factors intrinsic to the carotenoids and their food source.

Previously, we found a dose-responsive relationship between vitamin A intake from plant as well as from animal foods and serum retinol concentration in women in Central Java, Indonesia (de Pee *et al*, 1998b). We have now analysed those data to determine for which segment of the population a higher vitamin A intake from plant or animal foods was related to a higher serum retinol concentration and for which segment of the population it was not. If factors can be identified that are related to the probability of benefiting from an increased intake of vegetables, the design of food-based interventions can be optimised. The data used were collected as part of a nutrition surveillance system in Central Java.

Subjects and methods

Subjects and sampling design
The data used for the analysis were collected during the third round of data collection of the Central Java nutrition surveillance system (June–August 1996). These included data on socio-economic status, food production, food consumption, vitamin A intake, anthropometry and morbidity, from a total of 7196 households with a child ≤ 36 months old. The surveillance system has been described in more detail elsewhere (de Pee *et al,* 1998b). In short, multistage cluster sampling was used to select 40 households from 30 villages in each of six ecological zones ($n = 180$ villages). For blood collection from mother and child, a subsample of six villages was randomly selected per zone ($n = 36$ villages) and from these, all households with a child ≤ 24 months old were selected (in total $n = 1134$). Data from the women included in this subsample are reported in this paper.

The social marketing campaign and the nutrition surveillance system are both official parts of the program of the Ministry of Health and as such underwent careful review before being implemented. Written informed consent was obtained before blood collection.

Methods

General questionnaire. A general questionnaire collected information on household composition, educational background of the parents, sanitary conditions, household use of cooking oil and coconuts, and source, preparation and consumption of vegetables. In addition, anthropometric measurements were taken and data on vitamin A intake and morbidity were collected. Graduates from Indonesian schools of dietetics collected the data. Cooking oil used per person per day was calculated by dividing the weekly amount used by the household by 7 d and by the number of family members living in the house, counting children under 6 y old for 50%.

Anthropometry. Weight was measured to the nearest 0.1 kg with a UNICEF mother and child weighing scale. Height was measured to the nearest 0.1 cm using a microtoise. Mid-upper-arm circumference was measured to the nearest 0.1 cm with a measuring tape distributed by the Indonesian Ministry of Health.

Vitamin A intake. Vitamin A intake was collected with a semi-quantitative 24 h recall questionnaire, described in detail elsewhere (de Pee et al, 1998b). In short, a 24 h recall questionnaire was administered, vitamin A containing foods were classified into five categories for source and content of vitamin A (low and high vitamin A animal foods and low, medium or high vitamin A plant foods), and into three categories for portion size (small, medium or large).

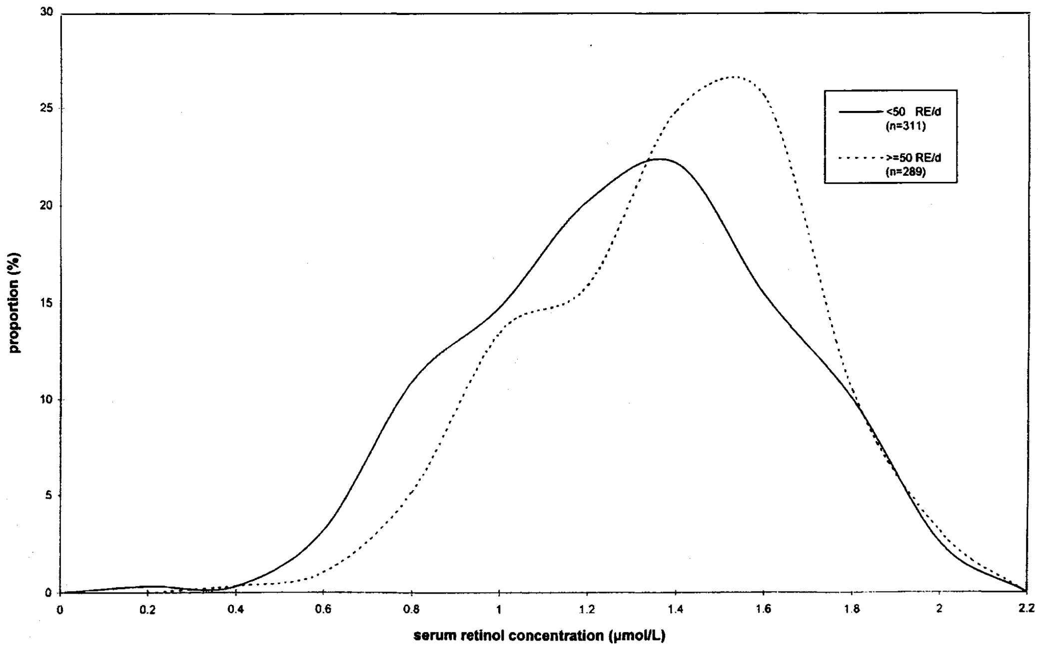

Figure 1 Distribution curves of serum retinol concentration (mean [95% CI] (n)) for women whose vitamin A intake from animal foods was below (1.28 [1.24–1.32] (311)) or above (1.38 [1.35–1.42] (289)) the median of the study population (50 RE/d). The difference between the two groups was significant (t-test, $P < 0.05$). Curves were constructed using intervals of 0.20 μmol/L, starting from 0.10–0.30 μmol/L. (N.B. The smoothness of distribution curves depends on the width of the intervals chosen and every distribution curve is, by definition, composed of the curves of its subpopulations. In this case, no possible subpopulations were excluded).

Vitamin A content of foods was obtained from Indonesian food composition tables (Ministry of Health, Indonesia, 1995; Hardinsyah & Briawan, 1994; and Nio, 1992). For calculating vitamin A intake, multipliers were set for all categories.

Biochemical indicators. Venous blood samples (3 mL) were drawn in the morning. Haemoglobin concentration was analysed immediately with the Hemocue device (Hemocue, Angelholm, Sweden). When anaemia was diagnosed, women were referred to the local health care centre. At the location of blood collection, serum was separated from the remaining blood by centrifugation. Serum was kept in the dark in a portable refrigerator operated on a car's cigarette lighter for a maximum of two days. After that, serum was stored at −20°C until analysis of retinol at the Nutrition Research and Development Centre in Bogor, within 3 months after blood collection. Analysis was done by HPLC (column, Bondapak C18, Waters, Milford, MA; detector, Shimadzu SPD-6AV, Tokyo, Japan; standards, Sigma; solvent, Merck, Whitehouse Station, NJ, USA) with methanol/water (90/10 v/v) as mobile phase (Arroyave *et al*, 1982).

Data-analysis

Construction of distribution curves. Distribution curves were constructed by calculating the percentage of women within 0.20 μmol/L intervals of serum retinol concentration (0.10–0.30; 0.30–0.50; 0.50–0.70 etc). The values on the x-axis of the curves represent the midpoints of the intervals (Figures 1 and 2). Cumulative distribution curves for plant vitamin A intake below and above the median crossed each other at a serum retinol concentration of 1.10 μmol/L (data not shown).

Statistical analysis. Differences between groups were examined by analysis of variance for normally distributed parameters, by Mann–Whitney test for non-normally distributed parameters, and by chi-square test for proportions (Snedecor & Cochran, 1980). For multivariate analysis, multiple logistic regression analysis was used (Snedecor & Cochran, 1980). Spearman-rank-correlation coefficients were calculated to assess the association between non-normally distributed parameters (Snedecor & Cochran, 1980). A P-value <0.05 was considered significant, while for analyses where trends were important P-values <0.10 were also reported. Analyses were conducted using SPSS for Windows version 6.1 (SPSS Inc, Chicago, IL).

Results

From the 1134 women selected for blood collection, 623 provided a blood sample (55%). The participation per village ranged from 32–93%. Data are reported for the 600 women for whom complete data sets were available. The women in the subsample ($n=600$) differed significantly from the other women selected for blood collection ($n=534$) for a few of all the variables reported in this paper: they had a younger child (10.8 *vs* 12.7 months), a lower body weight (47.7 *vs* 48.8 kg) and a smaller MUAC

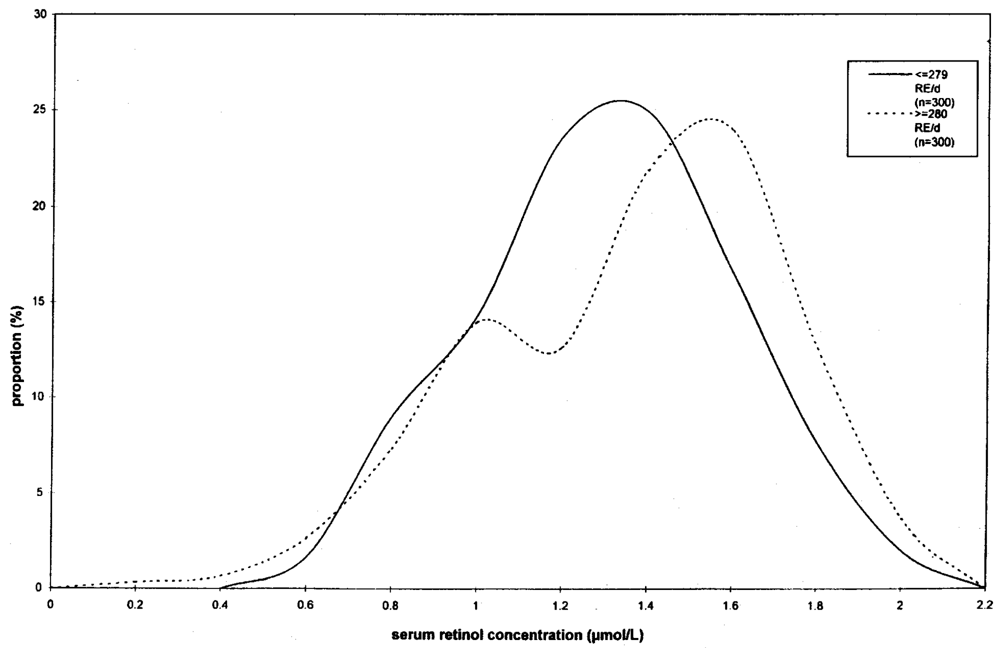

Figure 2 Distribution curves of serum retinol concentration (mean [95% CI] (n)) for women whose vitamin A intake from plant foods was below (1.30 [1.27–1.34] (300)) or above (1.36 [1.32–1.40] (300)) the median of the study population (279 RE/d). The difference between the two groups was significant (t-test, $P<0.05$). Curves were constructed using intervals of 0.20 μmol/L, staring from 0.10–0.30 μmol/L (see N.B. of Figure 1).

Table 1 Characteristics of women with a child ≤24 months old[a]

Characteristic	
Age (y)	27 ± 6
Age of child (months)	11 ± 6
Height (m)	1.49 ± 0.05
Weight (kg)	47.7 ± 7.2
Body mass index (kg/m²)	20.9 (18.0–25.2)
Mid-upper-arm circumference (cm)	24.4 ± 2.6
Serum retinol concentration (μmol/L)	1.33 ± 0.33
Haemoglobin concentration (g/L)	127 ± 14
Vitamin A intake from plant foods (RE/d)	279 (25–650)
Vitamin A intake from animal foods (RE/d)	30 (0–150)
Total dietary vitamin A intake (RE/d)	335 (63–750)
Breastfeeding exclusive (%)	12.8
not exclusive (%)	80.8
Vitamin A capsule after delivery (%)	11.5
Education woman ≥ secondary school (%)	31.7
Education husband ≥ secondary school (%)	37.8
Cooking oil used/person/day (mL)	22 (10–44)
Using closed latrine (%)	43.0
Owning home garden (%)	22.0

[a]Values are mean ± s.d., median (10–90 percentile) or proportion, n = 600.

(24.4 *vs* 24.7 cm). They also differed significantly from the total group of women not included in the subsample ($n = 6595$) for a few variables: they had a younger child (10.8 *vs* 11.7 months), a lower body weight (47.7 *vs* 48.6 kg), a smaller stature (1.49 *vs* 1.50 m), more of them were breastfeeding (93.7% *vs* 85.4%) and fewer of them had a home garden (22 *vs* 27%). However, it is unlikely that these factors affect the relationship of interest in this paper, that between vitamin A intake and serum retinol concentration. Therefore, the results obtained for the subsample are believed to be representative for the population from which the sample was drawn.

Basic characteristics of the women are shown in Table 1. According to Indonesian cut-off levels, 15% of the women were underweight (BMI $< 18.5\,kg/m^2$), while 5% were obese (BMI $> 27\,kg/m^2$). The proportion of women with serum retinol concentration $< 0.70\,\mu mol/L$ and $< 1.05\,\mu mol/L$ was 2.7% and 20.3%, respectively. Anemia was found in 24% of the women (Hb < 120 g/L).

There was a dose-responsive relationship between vitamin A intake from plant and animal foods and serum retinol concentration. Serum retinol concentrations for quartiles of vitamin A intake from plant foods (RE/d: ≤60; 61–279; 280–420; ≥421) were (μmol/L, mean [95% CI] (n)): 1.31a [1.25–1.36] (141); 1.30a [1.25–1.35] (159); 1.33ab [1.27–1.39] (149); and 1.38b [1.33–1.44] (151), while serum retinol concentrations for quartiles of vitamin A intake from animal foods (RE/d: < 50; 50–75; > 75) were: 1.28a [1.24–1.32] (311); 1.33a [1.28–1.38] (142); and 1.43b [1.38–1.48] (147) (quartiles with different letters are significantly different, ANOVA with post-hoc multiple comparisons test for least-significant difference; note that the first two quartiles of vitamin A intake from animal foods were combined, because 40% of the women had not consumed vitamin A from animal foods). Vitamin A intake from plant and animal foods were negatively correlated ($r = -0.11$, $P < 0.01$).

Previous analysis of this dataset showed that factors related to serum retinol concentration included, in addition to vitamin A intake from plant and animal foods, physiological factors, such as haemoglobin concentration, age of the youngest child and breastfeeding status, and home gardening and woman's education level, an indicator of socio-economic status (de Pee *et al*, 1998b). In this paper, we will thoroughly examine the relationship between vitamin A intake and vitamin A status for different subgroups of the population.

The distribution curves of serum retinol concentration by vitamin A intake from animal and plant foods are shown in Figures 1 and 2, respectively. The curve of women whose vitamin A intake from animal foods was above the median of the population was shifted towards higher serum retinol concentrations, as compared to the curve of the women whose intake was below the median. The distribution curve of women whose vitamin A intake from plant foods was above the median of the population, was also shifted towards higher concentrations, except for the women at the left tail of the curve, for example, with the lowest serum retinol concentrations. This subgroup of 25% of the women (75 out of 300), had a serum retinol concentration $< 1.10\,\mu mol/L$ (intervals in that range were 0.90–1.10 and 1.10–1.30 μmol/L, with mid-points of 1.00 and 1.20 μmol/L, respectively). The question to be answered in this paper is what factors affect these relationships of vitamin A intake, from animal or plant foods, and serum retinol concentration within different subgroups.

Table 2 compares characteristics among different groups of women: women with a serum retinol concentration $< 1.10\,\mu mol/L$ and a vitamin A intake from plant foods below or above the median; women with a serum retinol concentration $\geq 1.10\,\mu mol/L$ and a vitamin A intake from plant foods below or above the median; and women with a vitamin A intake from plant foods above the median and a serum retinol concentration below or above 1.10 μmol/L. Multiple logistic regression analysis was used to determine which characteristics, in addition to the characteristics that formed the basis of the division into two groups, were most strongly related to the differences among two groups (Table 3). Among women with a serum retinol concentration $< 1.10\,\mu mol/L$, women with a vitamin A intake from plant foods below or above the median differed, in addition to a small difference of age of the child and breastfeeding status, only with respect to ownership of a home garden (first column). Their distribution of serum retinol concentrations was not different. Among women with a serum retinol concentration $\geq 1.10\,\mu mol/L$, women with a higher vitamin A intake from plant foods, made more use of a closed latrine and used more cooking oil per person per day (second column), and their serum retinol concentration was shifted towards higher concentrations, relative to that of women with a lower vitamin A intake from plant foods. Among women with a vitamin A intake from plant foods above the median, those whose serum retinol concentration was $< 1.10\,\mu mol/L$, and unshifted, had a lower vitamin A intake from animal foods, a lower education level, a lower haemoglobin concentration, and an older child, as compared to women with a serum retinol concentration $\geq 1.10\,\mu mol/L$ (third column).

Similar comparisons of characteristics among subgroups of women are shown in Tables 4 and 5 for vitamin A intake from animal foods. Among women with a serum retinol concentration $< 1.10\,\mu mol/L$, the women with a higher vitamin A intake from animal foods made more use of a closed latrine, had a higher education level and more of them had received a vitamin A capsule after delivery, as compared to the women with a lower vitamin A intake from animal foods (first column of Table 5), and their serum retinol concentration was shifted as compared to that

Table 2 Characteristics of women with a child $\leq$24 months old and a serum retinol concentration below or above 1.10 μmol/L by vitamin A intake from plant-foods below or above the median of the group (279 RE/d)[a]

	Serum retinol concentration < 1.10 µmol/L			*Serum retinol concentration ≥ 1.10 µmol/L*			
Characteristics	*Plant vitamin A intake < median (n = 75)*[a,b]	*Plant vitamin A intake > median (n = 75)*[a,b]	*P-value*	*Plant vitamin A intake < median (n = 225)*[a,b]	*Plant vitamin A intake > median (n' 225)*[a,b]	*P-value*	*P-value for comparison of women with plant vitamin A intake > median and serum retinol concentration < 1.00 or ≥ 1.00 µmol/L (2nd and 4th data column of this table)*
Age of child (months)	11.9 ± 5.0	11.6 ± 6.2		10.8 ± 6.3	10.2 ± 6.5		
Breastfeeding exclusive (%)	5.3	9.3		15.1	14.2		
not exclusive (%)	92.0	81.3		78.7	79.1		
Haemoglobin concentration (g/L)	122 ± 13	125 ± 13		127 ± 15	129 ± 13		$P < 0.05$[b]
Vitamin A capsule after delivery (%)	10.7	8.0		11.6	12.9		
Education woman ≥ secondary school (%)	25.3	20.0		31.1	38.2		$P < 0.01$[c]
Education husband ≥ secondary school (%)	34.7	28.0		36.0	44.0	$P < 0.10$[c]	$P < 0.05$[c]
Using closed latrine (%)	33.3	34.7		40.9	51.1	$P < 0.05$[c]	$P < 0.05$[c]
Cooking oil used/person/day (mL)	20 (14–32)	24 (17–33)	$P < 0.10$[d]	20(14–29)	25 (18–33)	$P < 0.01$[b]	
Owning home garden (%)	8.0	22.7	$P < 0.05$[c]	21.3	27.1		
Vitamin A from animal foods (RE/d)	30 (0–90)	0 (0–75)		30 (0–90)	60 (0–90)		$P < 0.01$[d]
Vitamin A from plant foods (RE/d)	63 (35–140)	388 (320–638)	$P < 0.001$[d]	63 (30–145)	495 (345–638)	$P < 0.001$[d]	

[a]Values are mean ± s.d. median (25–75 percentile), or proportion.
[b]Student's t-test.
[c]Chi-square test.
[d]Mann–Whitney test.

of women with a lower animal vitamin A intake. A similar pattern was seen among women with a serum retinol concentration $\geq$ 1.10 μmol/L. Among women with a vitamin A intake from animal foods above the median, the only differences among the women with a serum retinol concentration below or above 1.10 μmol/L was their haemoglobin concentration and their vitamin A intake from animal foods (last columns of Tables 4 and 5).

Characteristics of women with a serum retinol concentration < 1.10 μmol/L and vitamin A intake from plant or animal foods above the median are shown in Table 6. The women with a vitamin A intake from animal foods above the median, whose serum retinol concentration was shifted relative to those with an intake below the median, had a higher education level as compared to the women with a vitamin A intake from plant foods above the median, whose serum retinol concentration was not shifted relative to those with an intake below the median.

Discussion

For women with a vitamin A intake, from animal or plant foods, above the median, the distribution curve of serum retinol concentrations was shifted towards higher concentrations, except for the subgroup of 25% of the women with a plant vitamin A intake above the median that had the lowest serum retinol concentrations. These women had a lower socio-economic status as compared to the 75% with a higher serum retinol concentration.

As previously reported, the vitamin A intake from plant foods was eight times higher than from animal foods, but the difference in serum retinol concentration among the groups with an intake below and above the median was almost the same for animal and plant foods (de Pee *et al,* 1998b). This confirmed that plant foods seem to be 16–23% as effective in increasing vitamin A status (de Pee *et al,* 1998a and 1998b) as has been assumed (FAO/WHO, 1988). The question now is why the positive relationship between vitamin A intake from plant foods and serum retinol concentration did not seem to exist for women with a relatively low serum retinol concentration.

First we should examine whether the method used for collecting data on vitamin A intake was appropriate. The fact that the data on vitamin A intake were related to vitamin A status in a dose-responsive manner shows that the method was appropriate for ranking women into quartiles of vitamin A intake. Misranking will have occurred, however not in a systematic way and not only for plant vitamin A intake of women with a vitamin A intake from plant foods above the median and a relatively low serum retinol concentration. Also, the method ranked women very well by vitamin A intake from animal foods: among women with a vitamin A intake from animal foods above the median, those with a serum retinol concentration < 1.10 μmol/L had a lower vitamin A intake from animal foods as compared to the women with a higher serum retinol concentration (Table 4). Such a difference among women with a serum retinol concentration below or above 1.10 μmol/L was not found for vitamin A intake from plant foods above the median (Table 2). Therefore, the serum retinol concentration of women whose vitamin A intake from plant foods was above the median but who had a relatively low serum retinol concentration, was indeed lower than expected based on their vitamin A intake from plant foods.

Table 3 Multiple logistic regression analysis for characteristics of women with a child ≤ 24 months old and a serum retinol concentration below or above 1.10 μmol/L by vitamin A intake from plant foods below or above the median of the group (279 RE/d), see also Table 2[a,b]

	Serum retinol concentration < 1.10 µmol/L, odds ratio for plant Vitamin A intake > median			*Serum retinol concentration ≥ 1.10 µmol/L, odds ratio for plant Vitamin A intake > median*			*Plant vitamin A intake > median odds ratio for serum retinol concentration ≥ 1.10 µmol/L*		
Variables	*OR*	*95%CI*	*P-value*	*OR*	*95%CI*	*P-value*	*OR*	*95%CI*	*P-value*
Haemoglobin concentration g/L	1.03	[1.00–1.06]	$P<0.10$	—	—	—	1.03	[1.01–1.05]	$P<0.01$
Age of child (months)[c]	0.97	[0.83–1.14]	ns[d]	—	—	—	0.96	[0.92–1.00]	$P<0.05$
Breastfeeding[c]: exclusive	1.00		—	—	—	—	—	—	—
not exclusive	0.13	[0.01–2.09]	ns	—	—	—	—	—	—
not breastfeeding	0.06	[0.00–6.62]	ns	—	—	—	—	—	—
Age (months) breastfeeding[c]: exclusive	1.00		—	—	—	—	—	—	—
not exclusive	1.21	[0.81–1.80]	ns	—	—	—	—	—	—
not breastfeeding	1.43	[0.89–2.29]	ns	—	—	—	—	—	—
Owning home garden	4.09	[1.44–11.58]	$P<0.01$	—	—	—	—	—	—
Woman's education ≤ primary school	—	—	—	—	—	—	1.00		
≥ secondary school	—	—	—	—	—	—	2.16	[1.11–4.18]	$P<0.05$
Using closed latrine	—	—	—	1.43	[0.98–2.09]	$P<0.10$	—	—	—
Cooking oil used/person/day < 15.6 (ml)	—	—	—	1.00[e]	—	—	—	—	—
15.6–21.9 (mL)	—	—	—	1.44	[0.84–2.48]	ns	—	—	—
22.0–31.1 (mL)	—	—	—	1.43	[0.82–2.49]	ns	—	—	—
≥ 31.2 (mL)	—	—	—	2.35	[1.36–4.04]	$P<0.01$	—	—	—
Animal vitamin A < 50 (RE/d)	—	—	—	—	—	—	1.00		
50–75 (RE/d)	—	—	—	—	—	—	1.42	[0.75–2.70]	ns
> 75 (RE/d)	—	—	—	—	—	—	2.70	[1.16–6.27]	$P<0.05$

[a]Variables available for stepwise entrance into the multiple logistic regression models which did not enter any of the three models were receipt of vitamin A capsule after delivery, and husband's education.
[b]Vitamin A intake from plant foods was not available for entrance into the logistic regression model, because the division in subgroups was based on vitamin A intake from plant foods.
[c]For the first column, the interaction term for age of the child and breastfeeding status entered the model with stepwise entrance ($P<0.05$). Therefore, the logistic regression was re-run with forced entrance for all variables that had entered upon stepwise entrance.
[d]non-significant ($P>0.10$)
[e]Overall P-value for cooking oil used, $P<0.05$
[f]Overall P-value for vitamin A from animal foods, $P<0.10$.

Table 4 Characteristics of women with a child ≤24 months old and a serum retinol concentration below or above 1.10 μmol/L by vitamin A intake from animal foods below or above the median of the group (50 RE/d)[a,b]

Characteristics	Serum retinol concentration < 1.10 μmol/L: Animal vitamin A intake < median (n = 92)[a]	Serum retinol concentration < 1.10 μmol/L: Animal vitamin A intake > median (n = 58)[a]	P-value	Serum retinol concentration ≥ 1.10 μmol/L: Animal vitamin A intake < median (n = 219)[a]	Serum retinol concentration ≥ 1.10 μmol/L: Animal vitamin A intake > median (n = 231)[a]	P-value	P-value for comparison of women with animal vitamin A intake > median and serum retinol concentration ≤1.10 or ≥1.10 μmol/L (2nd and 4th data column of this table)
Age of child (months)	12.0 ± 5.7	11.4 ± 5.5		11.3 ± 6.1	10.7 ± 6.6		
Breastfeeding exclusive (%)	6.5	8.6		14.6	14.7		
non-exclusive (%)	88.0	84.5		80.4	77.5		
Haemoglobin concentration (g/L)	123 ± 13	123 ± 12		128 ± 13	128 ± 15		$P < 0.05$
Vitamin A capsule after delivery (%)	2.2	20.7	$P < 0.001$[c]	10.5	13.9		
Education woman ≥ secondary school (%)	10.9	41.4	$P < 0.001$[c]	25.6	43.3	$P < 0.001$[c]	
Education husband ≥ secondary school (%)	26.1	39.7	$P < 0.10$[c]	31.5	48.1	$P < 0.001$[c]	
Using closed latrine (%)	23.9	50.0	$P < 0.01$[a]	33.8	57.6	$P < 0.001$[c]	
Cooking oil used/person/day (mL)	22 (16–32)	24 (16–33)		22 (16–29)	24 (16–32)		
Owning home garden (%)	15.2	15.5		28.3	20.3	$P < 0.05$[c]	
Vitamin A from animal foods (RE/d)	0 (0–0)	75 (75–150)	$P < 0.001$[d]	0 (0–0)	90 (75–150)	$P < 0.001$[d]	$P < 0.10$
Vitamin A from plant foods (RE/d)	313 (81–558)	140 (38–371)	$P < 0.05$[d]	265 (63–600)	300 (63–395)		

[a]Values are mean ± s.d., median (25–75 percentile), or proportion.
[b]Student's t-test.
[c]Chi-square test.
[d]Mann–Whitney test.

Before hypothesising why their serum retinol concentration could have been lower, possible modifiers of the serum retinol concentration should be examined. The first possible modifier is infection, because it can temporarily reduce serum retinol concentration (Northrop-Clewes *et al*, 1996). However, it is unlikely that this would only have occurred in the group of women whose vitamin A intake from plant foods was above the median. The second possible modifier is vitamin A intake from animal foods, which was lower for the women whose vitamin A intake from plant foods was above the median and who had a relatively low serum retinol concentration as compared to those with a higher serum retinol concentration. However, vitamin A intake from animal foods was not different among women with a serum retinol concentration ≥ 1.10 μmol/L and a vitamin A intake from plant foods below or above the median, while their curves were shifted relative to each other (Tables 2 and 3).

Therefore, the question remains why for women with a vitamin A intake from plant foods above the median the distribution curve of serum retinol concentration was only shifted towards higher concentrations for women with a serum retinol concentration ≥ 1.10 μmol/L. The second columns of Tables 2 and 3 show that these women, as compared to the women with a vitamin A intake from plant foods below the median, had a higher vitamin A intake from vegetables, as well as a higher socio-economic status, as indicated by the use of closed latrines and consumption of cooking oil. The consumption of cooking oil is more likely to reflect socio-economic status than bioavailability of vegetables carotenoids, because cooking oil consumption was almost the same as among women with a serum retinol concentration < 1.10 μmol/L (Table 4). For women with a serum retinol concentration < 1.10 μmol/L, the only difference among women with a vitamin A intake from plant foods below or above the median, apart from the age of the child and breastfeeding status, was ownership of a home garden, which reflects access to vegetables. Therefore, vitamin A intake from plant foods does not seem to be related to socio-economic status, but the relationship between vitamin A intake from plant foods and serum retinol concentration may be affected by socio-economic status. In fact, among women with a vitamin A intake from plant foods above the median, women with a serum retinol concentration < 1.10 μmol/L had a lower socio-economic status as compared to the women with a serum retinol concentration ≥ 1.10 μmol/L, as indicated by a lower education level and a lower vitamin A intake from animal foods (last column of Table 3).

However, the question is what is more important, the difference in vitamin A intake from animal foods or the difference in socio-economic status. As discussed above, animal vitamin A intake was not related to the different positions of the distribution curves of serum retinol concentration for women with a plant vitamin A intake below or above the median and a serum retinol concentration ≥ 1.10 μmol/L. Therefore, it is more likely that the difference in vitamin A intake from animal foods reflects a difference in socio-economic status, which in turn affects the relationship between vitamin A intake from plant foods and serum retinol concentration.

The strong relationship between vitamin A intake from animal foods and socio-economic status is illustrated in Tables 4 and 5. Women with a higher vitamin A intake from animal foods had a higher education level and more

Table 5 Multiple logistic regression analysis for characteristics of women with a child ≤ 24 months old and a serum retinol concentration below or above 1.10 μmol/L and vitamin A intake from animal foods below or above the median of the group (50 RE/d), see also Table 4[a,b]

	Serum retinol concentration < 1.10 μmol/L, odds ratio for animal vitamin A intake > median			*Serum retinol concentration ≥ 1.10 μmol/L, odds ratio for animal vitamin A intake > median*			*Animal vitamin A intake > median, odds ratio for serum retinol concentration ≥ 1.10 μmol/L*		
Variables	*OR*	*95% CI*	*P-value*	*OR*	*95% CI*	*P-value*	*OR*	*95% CI*	*P-value*
Haemoglobin concentration (g/L)	—	—	—	—	—	—	1.02	[1.00–1.04]	$P<0.10$
Vitamin A capsule after delivery	8.44	[1.68–42.47]	$P<0.01$	—	—	—	—	—	—
Woman's education ≤ primary school	1.00			1.00			—	—	—
≥ secondary school	3.82	[1.55–9.43]	$P<0.01$	1.70	[1.11–2.60]	$P<0.05$	—	—	—
Using closed latrine	2.40	[1.11–5.22]	$P<0.05$	2.27	[1.52–3.40]	$P<0.001$	—	—	—

[a]Variables available for stepwise entrance into the multiple logistic regression model which did not enter any of the three models shown here were age of the child, breastfeeding status, cooking oil used/person/day, husband's education, vitamin A intake from plant foods, and ownership of a home garden.
[b]Vitamin A intake from animal foods was not available for entrance into the logistic regression model, because the division in subgroups was based on vitamin A intake from animal foods.

Table 6 Characteristics of women with a child ≤ 24 months old, serum retinol concentration < 1.10 μmol/L and vitamin A intake from plant or animal foods > median of the group[a,b]

Characteristics	*Vitamin A plant foods > median (279 RE/d) (n = 75)*	*Vitamin A animal foods > median (50 RE/d) (n = 58)*	
Age of child (months)	11.6 ± 6.2	11.4 ± 5.5	
Breastfeeding exclusive (%)	9.3	8.6	
not exclusive (%)	81.3	84.5	
Haemoglobin concentration (g/L)	125 ± 13	123 ± 12	
Vitamin A capsule after delivery (%)	8.0	20.7	$P<0.05$[c]
Education woman ≥ secondary school (%)	20.0	41.4	$P<0.01$[c]
Education husband ≥ secondary school (%)	28.0	39.7	
Using closed latrine (%)	34.7	50.0	$P<0.10$[c]
Cooking oil used/person/day (mL)	24 (17–33)	24 (16–33)	
Owning home garden (%)	22.7	15.5	
Vitamin A from animal foods (RE/d)	0 (0–75)	75 (75–150)	$P<0.001$[d]
Vitamin A from plant foods (RE/d)	388 (356–638)	140 (38–371)	$P<0.001$[d]

[a]27 of the women are included in both groups.
[b]Values are mean ± s.d., median (25–75 percentile) or proportion.
[c]Chi-square test.
[d]Mann–Whitney test.
Note: The multiple logistic regression model for the odds ratio of having an animal food intake > median of this group, included woman's education (OR [95% CI]: 2.82 [1.31–6.10], $P<0.01$). All characteristics listed in the table, except vitamin A intake from plant or animal foods, were available for stepwise entrance into the model.

access to a closed latrine as compared to women with a lower vitamin A intake from animal foods. The fact that receipt of a vitamin A capsule after delivery also entered the logistic regression model may indicate that the distribution of vitamin A capsules to women after delivery is biased towards women with a higher socio-economic status.

With respect to vitamin A intake from animal foods and serum retinol concentration, we conclude that women with a higher socio-economic status consumed more vitamin A from animal foods, and therefore had a higher serum retinol concentration. Therefore, socio-economic status determined vitamin A intake from animal foods, which then determined serum retinol concentration. For the relationship between vitamin A intake from plant foods and serum retinol concentration, the role of socio-economic status is more complex. It does not seem to affect vitamin A intake from plant foods itself, but rather its relationship with serum retinol concentration. The next question is how socio-economic status can affect the utilisation of provitamin A from plant foods.

The utilisation, or bioavailability and bioconversion, of dietary provitamin A carotenoids depends on factors intrinsic to the food or the meal, on factors intrinsic to the host, as well as on their interaction (de Pee & West, 1996). It is unlikely that socio-economic status affects the choice of vitamin A-rich plant foods consumed or the method of preparation, because vegetables are relatively cheap and choices therefore more culturally determined, and fruit consumption is very low in this area. Therefore, factors that are related to the vegetable sources of carotenoids are unlikely to be affected by a difference in socio-economic status. Other factors that could be related to socio-economic status are host-related factors, such as nutrient status, parasitic infestation and other infections.

In this population, nutritional status, as assessed using anthropometric indices, was not related to socio-economic status. Haemoglobin concentration, which was lower for women with a lower serum retinol concentration, is usually a consequence rather than a cause of a lower serum retinol concentration (Bloem, 1995). With respect to presence of parasitic infestation and evidence of current or recent infection, data were not collected, except for a clinical examination and measurement of body temperature. Blood was not collected from clinically sick women, and body temperature was normal (35.9–37.6°C). However, hygiene conditions are related to socio-economic status. When hygiene conditions are poorer, the risk of suffering from parasitic infestation and/or other infections of the gastro-intestinal tract is higher. Such infections can reduce the bioavailability of carotenoids from vegetables (Solomons, 1993). Therefore, a plausible hypothesis for how socio-economic status can affect the relationship between vitamin A intake from plant foods and serum retinol concentration, is that hygiene conditions of women with a lower socio-economic status are poorer and that, as a consequence, the condition of their gastro-intestinal tract is compromised, which reduces their ability to utilise plant carotenoids. An alternative hypothesis is that women with a lower socio-economic status suffer more from subclinical infections and therefore have a lower serum retinol concentration while their utilisation of plant carotenoids, and therefore their vitamin A status, is not affected. However, this hypothesis is less likely, because the intervention study with purified β-carotene found improvements of serum retinol concentration in all subjects, irrespective of the presence of, undetected, subclinical infections (de Pee *et al,* 1995).

If the hypothesis that women with a lower socio-economic status utilise plant carotenoids less well were true, it may seem strange that this phenomenon was not observed for utilisation of retinol from animal foods. However, it has been found that parasitic infestation had no effect on the absorption of a high, pharmaceutical, dose of retinol (Tanumihardjo *et al,* 1996). Therefore, it may well be that the absorption of retinol from animal foods is also relatively undisturbed by a compromised condition of the gastro-intestinal tract. That bioavailability and bioconversion of dietary carotenoids are vulnerable to parasitic infestation was recently shown in a study with red sweet potatoes and dark-green leafy vegetables (Jalal *et al,* 1998).

These current findings that not everyone seems to benefit from a larger intake of vitamin A from plant foods, but that it seems related to socio-economic status, is very interesting. It would imply that the group of the population that is most in need of vitamin A may be able to obtain it from supplements, fortified foods and animal foods, but not, or only to a very small extent, from plant foods, especially vegetables.

The fact that a recent study with breastfeeding women found no effect of an increased intake of dark-green leafy vegetables on vitamin A status (de Pee *et al,* 1995) may be partly explained by the hypothesis presented here. The women in that study were selected based on a low haemoglobin concentration, almost all of them were infested by parasites and their mean serum retinol concentration was 0.89 μmol/L. They therefore, represented the lower end of the distribution curve of their population. A similar study in the same area with anaemic school children, who were also almost all infested by parasites, found that vegetable consumption increased serum retinol concentration, but the increase was only 23% [8–46%] (mean [95%CI]) of the expected increase (de Pee *et al,* 1998a). Probably the most important explanation for the finding that the vitamin A status of the children improved after consumption of dark-green leafy vegetables is that the intensity of parasitic infestation among the children was much less than among the women (de Pee *et al,* 1998a).

Conclusion

This present study found that for women with a vitamin A intake, from animal or plant foods, above the median, the distribution curve of serum retinol concentrations was shifted toward higher concentrations, except for the subgroup of 25% of the women with a plant vitamin A intake above the median that had the lowest serum retinol concentrations. These women had a lower socio-economic status as compared to the 75% with a higher serum retinol concentration. This means that the subgroup that was most in need of vitamin A was not able to obtain it—to a measurable extent—from plant foods. The probability of benefiting or not benefiting seemed related to socio-economic status, possibly reflecting host conditions, such as parasitic infestation. Intervention studies should be done in different populations to reveal the benefit of an increased vitamin A intake from plant foods among people with different kinds and intensities of parasitic infestation.

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New issues in developing effective approaches for the prevention and control of vitamin A deficiency

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Abstract

Even mild to moderate vitamin A deficiency is now recognized as an important factor in child health and survival. This has given increased emphasis to the goal of virtually eliminating vitamin A deficiency and its consequences, including blindness, by the end of the decade. The implications of vitamin A deficiency, however, vary according to the group at risk, and this needs to be addressed when looking at ways to achieve the goal. In preschool children, vitamin A deficiency can lead to increased risk of mortality and morbidity and to blindness. In pregnant and lactating women, it can lead to night-blindness and appears to have implications for maternal morbidity and mortality. Although the immediate health consequences for schoolchildren and adolescents are not completely known, they are probably less dramatic. Nevertheless, it is clear that there is a cross-generational cycle leading to and perpetuating vitamin A deficiency in affected communities. This also has implications when addressing prevention and control strategies. The existing, somewhat successful approach has been to target children aged six months to six years; it is implicit that this criterion is used to measure progress towards the end-of-decade goals. A broader, complementary, life-cycle approach to vitamin A deficiency is now appropriate in many countries. There is increasing emphasis on such approaches, i.e., fortifying foods with vitamin A and improving the diet, which address the whole population at risk. A mix of interventions will give governments the chance to shift from a subsidized vitamin A capsule programme to more sustainable, non-subsidized, consumer-funded vitamin A interventions, although in an appreciable number of countries, supplementation with vitamin A will be a necessity for some years to come. Guidelines to assist governments in such transitions are a high priority.

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Introduction

Vitamin A deficiency has been known to be the underlying cause of xerophthalmia for many centuries. The recognition of the clinical signs has obscured the fact that subclinical vitamin A deficiency is prevalent among large segments of the populations of many countries. This deficiency critically affects the health and well-being of these societies, since a series of large intervention trials has shown that even mild to moderate vitamin A deficiency is an important factor in child health and survival [1].

The United Nations, through UNICEF, convened the World Summit for Children in September 1990 to discuss a plan of action for improving the condition of women and children worldwide. Over 70 heads of state ratified a global plan of action, which included 27 social and health goals to be achieved by the year 2000. The plan details how the rights of women and children to adequate and dignified survival and development can be guaranteed. Among the other goals were nutrition goals, including the virtual elimination of vitamin A deficiency and its consequences, including blindness. Two years later, the World Declaration and Plan of Action for Nutrition of the International Conference of Nutrition at Rome in December 1992 reaffirmed the goal of eliminating vitamin A deficiency before the end of the decade.

The question of why, amidst an abundance of plant sources of provitamin A, children still become blind from vitamin A deficiency was first raised by H.A.P.C. Oomen in Indonesia in the early part of this century. Lack of knowledge and lack of care were found to be the major underlying causes. However, it has recently become evident that the bioavailability of provitamin A from plant foods, especially from dark-green leafy vegetables and to some extent also from fruits and tubers, is much lower than what has been assumed [2-

4]. In general, currently used food-composition tables overestimate the vitamin A content of dark-green leafy vegetables by a factor of approximately 4 to 6 [3, 4] and that of fruits by a factor of approximately 2 [3]. The degree of overestimation can range from as little as 1 to as much as 15, depending upon several factors, such as the method used for analysing carotene content, the food source of carotenoids, the preparation methods used, and the condition of the child (host) consuming the carotene source. However, whether it is a factor of 3 or a factor of 10, in countries where large segments of the population are dependent on dark-green leafy vegetables as their only source of vitamin A, there will be a high prevalence of subclinical vitamin A deficiency.

The implications of such vitamin A deficiency, however, vary according to the group at risk. In pre-school children, vitamin A deficiency can lead to increased risk of mortality and morbidity and to blindness. In pregnant and lactating women, it can lead to night-blindness and appears to have implications for maternal morbidity and mortality [5]. Although the immediate health consequences for schoolchildren and adolescents are not completely known, they are probably less dramatic (table 1).

The goal of this overview is to consider the implications of recognizing vitamin A deficiency as a potential problem in all age groups of a society rather than solely as a problem of pre-school children. This new paradigm—a life-cycle approach to vitamin A deficiency—will demonstrate the need for new strategies.

Assessment and analysis

The challenge of "virtually eliminating vitamin A deficiency and its consequences" has made governments face the need to determine the existence, severity, and extent of vitamin A deficiency in their populations. The reliability of such assessment depends on the validity and interpretation of the measures of vitamin A status employed. Vitamin A intake should be a leading indicator of vitamin A status at the population level, as a lack of vitamin A in the diet is the main underlying cause of vitamin A deficiency. However, because of the overestimation of dark-green leafy vegetables and fruits as a source of vitamin A, among other limitations, dietary methodology has not proven to be a very useful assessment tool.

Serum retinol levels, although not considered a reliable index of the subclinical vitamin A status of individuals, have proven to be a useful indicator at a population level, thus demonstrating that indicators used for population-based assessment can be of limited value for individual-based assessment but can still be useful for characterizing a population. In contrast to subclinical vitamin A deficiency, which is prevalent in large portions (30%–70%) of affected populations, clinical vitamin A deficiency (xerophthalmia) is clustered in the lowest socio-economic strata of villages and communities in poorer countries. Nevertheless, the prevalence of xerophthalmia can still be used to identify vitamin A deficiency in a population, because a population with an overall high prevalence of xerophthalmia will have an overall high prevalence of vitamin A deficiency. Xerophthalmia can be viewed as the tip of the iceberg for vitamin A deficiency (table 2).

Cut-off points are applied to laboratory findings for individual-based screening to estimate the prevalence of the condition of interest, in this case vitamin A deficiency. The only conventional and widely accepted biochemical criterion for the identification of populations at risk is a prevalence of 5% or more of serum retinol levels less than 10 µg/dl. A serious drawback of this approach is the tendency to regard only individuals below the cut-off as affected, and to focus intervention on those who meet the definition for the indicator, when in fact a much greater proportion of the population is affected. One way to avoid this pitfall is to present the entire distribution of the laboratory findings against a reference or standard distribution (which should be in a population largely free from vitamin A deficiency). The proper application of the prevalence of an indicator below a certain cut-off point is to view its prevalence as an index of the severity of the deficiency in the population.

Prevalence

Vitamin A deficiency is one of the most frequent nutritional deficiency disorders in the world. The World

TABLE 1. Public health implications of vitamin A deficiency according to risk group

Variable	Infants (6–12 mo)	Pre-school children	School-children	Adolescents	Pregnant women	Lactating women
Mortality	+	+	?	+	+	+
Severity of morbidity	–	+	?	?	+	+
Mild anaemia	±	+	+	+	+	+
Growth	?	±	?	?	?	–

TABLE 2. Biological indicators of vitamin A status

Indicator	Infants	Pre-school children	School-children	Adolescents	Pregnant women	Lactating women
Clinical signs	–	+	Night-blindness, Bitot's spots	Night-blindness?	Night-blindness	Night-blindness
Serum retinol	+	+	+	+	+	+
Breastmilk vitamin A	Indirect indicator?					
Vitamin A–related morbidity		+			+	+

Health Organization (WHO) has estimated that over 250 million children worldwide have deficient vitamin A stores [1]. The highest prevalence of vitamin A deficiency is found in pre-school children and in pregnant and lactating women, but subclinical vitamin A deficiency has also been shown to be common in school-children and adolescents in some settings. Almost all country prevalence data relate to vitamin A deficiency in pre-school children, which means that prevalence data from other age groups are frequently not available (table 1).

Requirements

Vitamin A is the generic term for all compounds that have the biological activity of retinol. In animals vitamin A exists largely in the preformed state as retinol or as its related compounds. In plants vitamin A occurs in the precursor or provitamin forms as carotenoids, which animals convert into preformed vitamin A after consuming them in the diet. The most widely distributed carotenoid is β-carotene. The relative amounts of vitamin A consumed as provitamins from plant sources and as preformed vitamin A from animal sources differ considerably in various parts of the world (table 3). In the average Western diet, about half of the vitamin A activity comes from plant carotenes. The remainder of the dietary vitamin A is obtained as preformed vitamin A from animal sources. In much of the developing world, up to 90% of the vitamin A in the diet is of plant origin. Sources of the provitamin A carotenoids include dark-green leafy vegetables, deep-yellow vegetables, and deep-yellow fruits. Sources of preformed vitamin A include liver, fish liver oil extracts, and egg yolks.

The apparent vitamin A activity of plant foods was recently been found to be much lower than had been assumed [2, 3]. An intervention study among school-children in Indonesia found that the apparent vitamin A activity of leafy vegetables and carrots was 23% of what had been assumed (95% confidence interval, 8% to 46%), and that the vitamin A activity of fruits was 50% of what had been assumed (95% confidence interval, 21% to 100%) [3]. These proportions were confirmed in a recent intervention study among breastfeeding women in Vietnam [7]. Vitamin A from plant sources largely comes from leafy vegetables and to a much smaller extent from roots, tubers, and fruits. In fact, recent analysis of cross-sectional data from women in Indonesia confirmed that the apparent vitamin A activity of plant foods was 16% to 23% of what had been previously assumed [4]. Therefore, we have chosen a factor of approximately five for adjusting vitamin A intake from plant foods.

TABLE 3. Available supply of vitamin A according to WHO region

Region	Vitamin A (mg RE/day)[a]			Incidence of xerophthalmia
	Vegetable	Animal	Total	
South-East Asia	378 (75)	53	431 (128)	1.45
Africa	654 (130)	122	776 (255)	1.04
Western Pacific	781 (156)	216	997 (372)	0.13
Eastern Mediterranean	591 (118)	345	936 (463)	0.12
Americas	519 (104)	295	814 (400)	0.06

Source: ref. 6.
a. Numbers in parentheses are adjusted for bioavailability.

Table 3 shows the vitamin A intake and the xerophthalmia rates by region. The gross figures do not show a significant correlation between the total vitamin A intake and reported rates of xerophthalmia (Spearman rank test, $R = .60$, $p = .285$). However, the adjusted vitamin A intake for the new conversion factor correlates significantly with the prevalence rates of xerophthalmia (Spearman rank test, $R = .90$, $p = .038$).

Causes of vitamin A deficiency

Figure 1 shows the conceptual framework of the causes of vitamin A deficiency. The conceptual framework of the causes of xerophthalmia is in principle the same. However, the role of contributing factors such as infection and protein–energy malnutrition is more important.

The main causes of vitamin A deficiency in the developing world are insufficient intake of vitamin A and poor bioavailability of provitamin A sources (vegetables and fruits). Important contributing factors to vitamin A deficiency are the increased requirements for vitamin A at certain stages in the life cycle (early childhood, pregnancy, and lactation) and during infection.

However, this simplified list does not address the many varied physiological, sociocultural, and geographic factors that also define the vitamin A status of a population. The conceptual framework clearly shows the role of the contributing factors. Coexisting health status affects vitamin A status both by affecting the metabolic processes and by reducing intake. The clustering of xerophthalmia, now widely described, points to the importance of sociocultural factors such as intrahousehold distribution. The different prevalence in boys and girls points to the impact of sex and intrahousehold distribution of food.

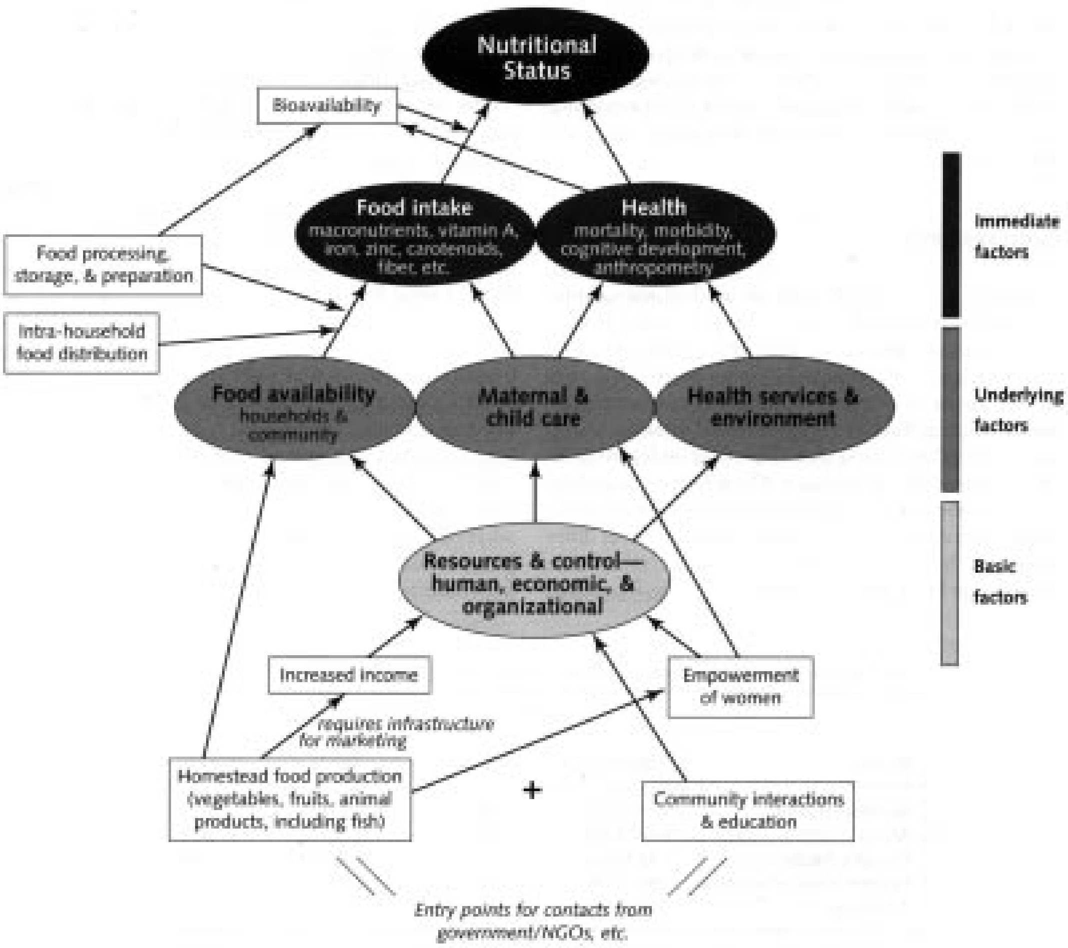

FIG. 1. Conceptual framework of causes of vitamin A deficiency

Consequences of vitamin A deficiency

Vitamin A deficiency and child mortality

Irreversible blindness is among the most dramatic consequences of vitamin A deficiency. As a result, there has been considerable emphasis on xerophthalmia, the eye changes due to vitamin A deficiency, and the most visible consequences of vitamin A deficiency. Nutritionists have tended to consider xerophthalmia a problem for those working in blindness prevention, whereas those involved in blindness prevention have considered it a problem for nutritionists. More recently, though, on the basis of the work of Sommer and others, vitamin A has become recognized as having an essential role in the prevention of childhood mortality and disability [1].

A series of eight controlled, community-based trials has been carried out since the first trial in Aceh [8-15]. Findings from all these trials were submitted to a comprehensive meta-analysis on the effectiveness of vitamin A supplementation in reducing child morbidity and mortality [16]. The reported impact has ranged from a 50% reduction in mortality rates among children under five years of age (Tamil Nadu) to no effect (Sudan). The meta-analysis, which included 8 of 10 formal field trials, showed a 23% reduction in mortality (95% confidence interval, 15% to 29%) for children aged 6 to 72 months. Estimated 95% confidence intervals were established under two models: a fixed effects model (R =. 77; 95% confidence interval, . 71 to . 84) and a random effects model (R =. 77; 95% confidence interval, . 68 to . 88).

Adequate vitamin A status prevents nutritional blindness and contributes significantly to child health and survival. Vitamin A plays an important role in preventing nutritional blindness and in reducing morbidity and mortality, from mid-infancy through the early school-age years, particularly from measles and diarrhoea.

Vitamin A deficiency and morbidity

The various studies on the association between vitamin A deficiency and morbidity have not had very consistent results [17-26]. This may be explained by the fact that morbidity studies are hard to carry out. Under- and overreporting, differences in definitions and severity, and differences in underlying factors such as malnutrition make these studies more difficult than studies on mortality, which have, among other things, the clearly defined end point of death. However, the lack of findings cannot be attributed only to poor methods, since studies of the effects of improvements in water supplies and excreta disposal were able to detect a reduction of 22% in morbidity rates using similar methods.

Increased morbidity and mortality occur at levels of vitamin A deficiency less severe and chronic than those required for night-blindness and xerophthalmia. Therefore, the definition of vitamin A deficiency for public health purposes must be revised and made more sensitive to milder degrees of deficiency.

Vitamin A deficiency and measles

Measles deserves separate consideration because it is a viral disease that infects and damages epithelial tissues throughout the body, and because it has been shown that measles plays an important role in corneal blindness. A relationship between measles and vitamin A has been recognized since the early 1930s [27]. It is now well known that measles can bring serum concentrations of vitamin A in well-nourished children to below those observed in non-infected malnourished children. Mean serum retinol levels have been shown to be significantly lower in children with corneal lesions than in those with normal corneas. Several studies have evaluated the treatment of severe measles with vitamin A [27-29]. In these trials, mortality was at least 50% lower among children who had been treated with large doses of vitamin A at admission. In each trial, the clinical severity of measles complications was lower among those who survived.

Vitamin A deficiency increases the severity, complications, and risk of death from measles. Improving vitamin A status before the onset of measles (prophylaxis), or after measles occurs (treatment), markedly reduces the severity of complications and associated mortality. Improving the vitamin A status of children with vitamin A deficiency and treating all cases of measles with vitamin A, even in populations in which xerophthalmia is rare, can substantially reduce childhood disease and mortality.

Vitamin A deficiency and women

Although vitamin A deficiency is a serious and dangerous deficiency in childhood, it has recently been recognized that its impact goes well beyond this age group. Publications from Indonesia and Malawi, and now Nepal, have shown that vitamin A deficiency in pregnancy is associated with anaemia, low vitamin A content of breastmilk, transmission of the human immunodeficiency virus (HIV) from mother to child [30-32], and probably a reduction in maternal mortality [5]. Stoltzfus et al. [31] showed that a high dose of vitamin A was an efficacious way to improve the vitamin A status of both mother and child. Suharno et al. [30] demonstrated the extent to which improvement in vitamin A status contributes to the treatment of anaemia in pregnancy. Semba et al. [32] showed that the mean vitamin A status of mothers who transmitted HIV to their infants was lower than that of mothers who did not transmit HIV.

These reports are of less public health importance when vitamin A deficiency in women is not very prevalent. A recent analysis from Bangladesh, however, showed that the prevalence of night-blindness among mothers was even higher than among pre-school children. Children of mothers with night-blindness showed a statistically significant increase in morbidity after potential confounding factors had been controlled [33]. Similar results have been reported in Nepal [34, 35]. A recent study by West et al. [12] showed that vitamin A or β-carotene supplementation to pregnant women may reduce maternal mortality by up to 50%.

It is well recognized that vitamin A deficiency clusters in households and is more likely to occur in siblings, and that children from the same household exhibit similar vitamin A status. It is, therefore, not surprising that this cluster effect extends to other vulnerable family members, notably women of reproductive age. It takes one to two years for a healthy adult to show signs of vitamin A deficiency, thereby making it likely that many of these mothers have been nutritionally compromised since their early childhood. In life-cycle terms, this means that young girls are starting out with low liver stores of vitamin A and never have a chance to catch up. By the time they are 18 and married, they too will give birth to children with low vitamin A stores. These children, a majority of whom are breastfed exclusively for the first months of life, then complete the generational cycle of vitamin A deficiency. Older and malnourished women in such societies have also been found to be at risk for night-blindness, which reinforces the above-mentioned hypothesis and emphasizes the need to take a life-cycle approach to vitamin A deficiency.

Vitamin A deficiency is prevalent among women in areas where vitamin A deficiency is endemic. Vitamin A deficiency in women has negative effects on the health status of both mothers and their offspring. Therefore, programmes should be developed to improve the vitamin A status of women, starting in early childhood and continuing during the reproductive years, for the sake of both their own and their children's health. Vitamin A interventions in pregnant women may reduce maternal mortality by up to 50%.

Vitamin A deficiency and anaemia

Vitamin A and its derivatives are important not only for the normal functioning of the eye but also for the normal differentiation of other cell systems in the body, including parts of the haematological system. Arrays of epidemiological studies have indicated that vitamin A deficiency and anaemia often coexist, and that there are significant associations between serum retinol and biochemical indicators of iron status [36-44]. A study of pregnant Indonesian women showed that 100% of the anaemic women were cured by combination therapy of vitamin A with iron, whereas only 40% were cured by vitamin A alone and only 60% by iron alone [40]. This clearly has important programmatic and policy implications. Recent work from Nepal by Stoltzfus et al. [45] showed that vitamin A supplementation improved only mild anaemia, and only in those women who were not infected by worms.

Improvement of iron status, when combined with vitamin A supplementation, will have an even greater impact on the prevalence of anaemia than the separate application of only one of these strategies. Vitamin A deficiency should be tackled by a combination of strategies, including dietary diversification, food fortification, vitamin A supplementation, and other public health measures such as promotion of breastfeeding and control of infectious disease, to achieve the virtual elimination of vitamin A deficiency (table 4).

Supplementation

The rationale for supplementation with high doses of vitamin A (retinol) rests on the fact that this fat-soluble nutrient can be stored in the body, principally in the liver. Periodic high-dose supplementation is intended to protect against vitamin A deficiency and its consequences by building up a reserve of the vitamin for periods of reduced dietary intake or increased needs [46].

TABLE 4. Strategies to combat vitamin A deficiency according to risk group

Strategy	Infants (0–6 mo)	Pre-school children	School-children	Adolescents	Pregnant women	Lactating women
Breastfeeding	++	+	–	–	–	–
Universal distribution of high-dose vitamin A	±	+	Not yet	Not yet	–	Postpartum
Low-dose vitamin A	+	+	+	+	+	+
Food-based	–	+	+	+	+	+
Fortification	+	+	+	+	+	+

High-dose vitamin A supplements for pre-school children, lactating women, and high-risk populations

The human liver has an enormous capacity to store vitamin A, allowing sufficient stores in the body to be laid down through periodic administration of large doses of the vitamin. The dose of vitamin A must be large enough to offer protection but not so large as to produce side effects. For individuals one year of age and older, administration of 200,000 IU (approximately 60,000 mg) of vitamin A will provide adequate protection for four to six months. There is now considerable experience with vitamin A supplementation programmes in countries such as Bangladesh and India, and they are known to be effective and safe. When vitamin A is administered in recommended doses, there are no serious or permanent adverse effects; such side effects as may occasionally occur (e.g., for infants, a tense or bulging fontanelle or vomiting) are minor and transitory and do not require specific treatment [46].

All mothers in high-risk regions should also receive a high dose of vitamin A within eight weeks of delivery. The capsule should be delivered as soon as possible after delivery, since this will increase the vitamin A levels in breastmilk [31]. It now appears this may also have beneficial effects for the mother herself [5].

Infants and children who have infections such as diarrhoea, measles, respiratory infections, and chickenpox or who are severely malnourished have an increased risk of vitamin A deficiency. Furthermore, work from Bangladesh, Indonesia, and Nepal has shown that severe vitamin A deficiency is clustered. It is, therefore, recommended that these children receive a high dose of vitamin A.

Low-dose vitamin A supplementation

Both severe vitamin A deficiency and excessive vitamin A are teratogenic in animals, although this observation has not been confirmed in humans. Adequate maternal vitamin A status ensures protection from the adverse consequences of either too much or too little vitamin A for the mother, foetus, and newborn [47]. Where habitual vitamin A intakes are low, a pregnant woman and her developing foetus are expected to benefit without risk from a daily vitamin A intake of 10,000 IU or a weekly intake of 25,000 IU from diet or supplementation or a combination of both. It has been suggested by Underwood and others (e.g., at the International Congress of Nutrition in Montreal in 1997) that these somewhat more physiological doses may have an added advantage over the high-dose regimens. A weekly dose was the method used in a recent study in Nepal showing an impact of both vitamin A and carotene separately on maternal mortality [5]. This also suggests that the form of the supplement may be relevant.

Fortification

Micronutrient interventions, particularly fortification, have been identified by the World Bank as among the most cost-effective of all health interventions [48]. There is a wealth of experience in the fortification of foods, and it has been a major factor in the control of micronutrient deficiencies in the industrialized world [49]. Until recently it was presumed that fortification was not a suitable intervention in the less industrialized countries, as the experience in developing countries has not always been encouraging [50]. There are now enough successful examples to suggest this is no longer true. Mora and Dary* list 17 countries in Latin America that now fortify with at least one micronutrient and sometimes more.

Vitamin A fortification has been important in reducing deficiencies of vitamin A, especially in Latin America, where sugar is fortified. Other vehicles have included fats and oils, tea, cereals, monosodium glutamate and instant noodles, as well as milk and milk powder, whole wheat, rice, salt, soya bean oil, and infant formulas [51]. For example, margarine is currently fortified with vitamin A in Brazil, Chile, Colombia, El Salvador, Mexico, the Philippines, and other countries around the world, including virtually all developed countries. In India red palm oil is added to other edible oils, and vitamin A–fortified soya bean oil is being tested in Brazil [52].

The most successful experience with vitamin A, outside the industrialized world where margarine and milk have been most important, is with sugar in Central and South America. Sugar was first fortified in Guatemala over 25 years ago. Despite the demonstrated success of the programme in the early 1970s, with increases in the status of recipients' vitamin A levels and, indirectly, haemoglobin levels, the programme faltered in the 1980s [53]. This was due to a lack of continuing government commitment, indifference from the producing sector, economic limitations, and, presumably, a lack of self-sustainability (in terms of passing on costs, etc.), so that it could not continue without some public-sector involvement. It has now been revitalized, although some technical improvements are still needed. In a start-up programme in Bolivia, in a partnership between government, donors (US Agency for International Development/OMNI, UNICEF), and a commercial firm, sustainability has yet to be assured, although there are currently plans for scaling up nationally by the private sector. Sugar has been fortified with vitamin A in Costa Rica, El Salvador, Guatemala, Honduras, and Panama [51]. Zambia has reached agreement to fortify its sugar in 1998. Other countries, such as the Philippines and Uganda, are also interested.

*Mora JO, Dary O. Strategies for prevention of micronutrient deficiency through food fortification. Lessons learned from Latin America. Presented at the 9th World Congress of Food Science and Technology, Budapest, Hungary, 1995.

An interesting programme using whole wheat was developed in Bangladesh with technical assistance and support from the US Agency for International Development through Helen Keller International. Wheat being the less preferred staple, the fortification programme would have been automatically targeted to the poor. It became, however, an example of a technically feasible, properly developed programme that failed politically because it did not adequately involve the policy makers and those most affected [54]. The Philippines is currently testing vitamin A fortification of wheat flour.

In both Indonesia and the Philippines, fortifying monosodium glutamate (MSG) with vitamin A had been shown to be technically feasible and had been properly developed by consumption, taste, and impact trials [55, 56]. It did not proceed because of a variety of technical, political, and food-industry reservations. Fortification of rice and other cereals is also technically feasible as a pilot, but the fortification of rice with vitamin A has not proceeded to the national level. In Brazil it is still at the stage of bioavailability testing [51]. In Venezuela, on the other hand, pre-cooked corn flour, used to make *arepas*, a staple food in the national diet, has been successfully fortified with vitamin A, iron, thiamine, riboflavin, and niacin [57].

Success in fortifying with vitamin A has depended on sustained political commitment (both in-country and, initially, by donors), persistence with technical development of fortificant technologies to overcome problems, and increased awareness of the health consequences of vitamin A deficiency by governments as well as involvement of the private sector. It has, however, now been shown to be effective in a variety of settings [51-53, 58].

Food-diversification programmes

Since inadequate intake of vitamin A is the main cause of vitamin A deficiency, the solution lies in providing adequate amounts of the vitamin to populations at risk. Vitamin A in foods consists of provitamin A sources and preformed vitamin A sources. Foods containing preformed vitamin A are expensive and beyond the regular reach of the poor, but alternative, less expensive sources of provitamin A are easily available. Home gardening is a traditional family food production system widely practised in many developing countries [59-61].

Despite this, vitamin A deficiency remains a public health problem in many of these countries. Provitamin A carotenoids are the major source of dietary vitamin A, with plant sources providing more than 80% of the total vitamin A intake. The intervention studies mentioned above have shown that leafy vegetables and carrots improve vitamin A status, but not as much as previously thought [3]. Fruits, including pumpkin and sweet potato, improve vitamin A status more than vegetables. This, the lower bioavailability of vitamin A in vegetables and fruits, and probably also the seasonal variability of production of vegetables and fruits in home gardens, are factors underlying the causes of vitamin A deficiency in these regions. However, vegetables and fruits are more than a possible source of vitamin A; the various carotenoids and other micronutrients they contain are important, because consumption of vegetables and fruits is associated with lower risk of degenerative diseases. A recent study in Nepal also showed that β-carotene had an effect on reducing maternal mortality, which is not the case for vitamin A [5].

It is, therefore, essential to maximize the effectiveness of home gardening as a strategy to combat vitamin A deficiency. Anecdotal experience suggests that home gardening (as a method of improving nutrition) has been generally successful at the pilot phase but has not often been scaled up successfully. Recent experience in Bangladesh, however, has demonstrated a successful example [60]. The International Union of Nutritional Sciences (IUNS) Committee II/B Food Gardening for Nutrition Improvement has made the following recommendations:

» Diversify food production
  - Where possible, include orange fruits, roots, and tubers;
  - Where possible, introduce animal husbandry, such as poultry and fish;

» Optimize the effect of vegetables through
  - Deworming;
  - Providing zinc supplements (which may improve carotene bioconversion, but this needs further research);
  - Maximizing nutrient intake and reducing the effect of matrix and absorption inhibitors by choice of foods and choice of preparation methods;
  - Using techniques of breeding, selection, and genetic engineering to improve carotene content and bioavailability.

Implementing small-scale horticultural strategies to increase effectiveness raises questions not always considered in nutrition and health programmes. These include agricultural issues (fences to keep chickens away from seeds and seedlings, seasonality in production, the need for preservation, etc.) and the feasibility of such measures as flood control, which alters conditions for fish farming, altering food practices, such as the consumption of fruits that are prematurely used as vegetables, and, perhaps most importantly, community-level constraints, such as socio-economic conditions. It is also suggested that where there is a traditional practice of home gardening, using such an approach to increase micronutrient intake is more likely to be successful.

Using vitamin A capsule programme evaluation to monitor progress in food-diversification and food-fortification programmes

For two decades now, at least four countries in South-East Asia (Bangladesh, India, Indonesia, and Vietnam) have had programmes implementing universal supplementation of vitamin A capsules, which, according to the World Bank, is one of the most cost-effective of health interventions. Although prophylactic vitamin A dosing does not address the underlying cause of vitamin A deficiency, the nutritional aim is to improve vitamin A status for several months by increasing liver stores and tissue concentrations of retinol, thereby reducing the risk and severity of vitamin A deficiency and its devastating sequela of blindness, as well as reducing the increased morbidity and mortality from infectious diseases as a consequence of vitamin A deficiency, while minimizing the risk of acute hypervitaminosis A.

Several studies have shown that high-potency vitamin A supplementation has an efficacy of 90% under controlled circumstances [62-65]. The reasons that the efficacy of vitamin A capsules is not 100% may be an inability of 200,000 IU to protect individuals who are at particularly high risk (repeated infections, virtual absence of dietary sources, or severe deficiency initially) for the full six months or programme-related issues (inadequate administration, misrecording, or partial delivery of the intended dose). The likely cause of early recurrence of vitamin A deficiency after a high-dose vitamin A capsule is poor dietary intake of vitamin A combined with infectious diseases.

Since the efficacy of vitamin A capsules is 90%, the effectiveness will reflect differences in programme performance under "real-life" circumstances. The theoretical effectiveness, or the expected reduction, is the product of efficacy and coverage. Two recent studies in the region studied the effectiveness of vitamin A capsule programmes [64, 65]. A study from Bangladesh found an effectiveness of 25%, with coverage of 48% in rural areas, and a higher effectiveness of 61%, with coverage of 93% in urban areas. The expected reductions under these circumstances were 90% × 48% = 43% and 90% x 93% =83%, respectively [1]. The lower effectiveness is most probably due to the low dietary vitamin A intake and high rate of infectious disease among pre-school-aged children in Bangladesh. The effectiveness of the vitamin A capsule programme was associated with the time lag between the distribution of the capsule and the moment of measurement of the impact. This implies that vitamin A supplementation would be more effective when given every four months.

During the past 10 years, substantial progress has been made, particularly in reducing the prevalence of vitamin A deficiency. The analysis of both the Bangladesh and Vietnam experiences showed that in terms of high effectiveness (Vietnam) or of a high time-response effectiveness (Bangladesh), the reduction in vitamin A deficiency in those countries has been mainly an effect of the vitamin A capsule programme, and that the underlying problem of lack of vitamin A in the diet (through fortification or through foods in the diet) has still not been solved. The governments, however, are now in the process of phasing out the vitamin A capsule programme, because the national prevalence of vitamin A deficiency is currently below the level that has been used to define the existence of a public health problem.

As the intake of vitamin A–rich sources in the diet increases as a result of fortification, changing diets, or both, the efficacy of vitamin A capsule supplementation will decrease (in Europe there is no impact of vitamin A supplementation on morbidity, mortality, or blindness). As a consequence, the effectiveness of the vitamin A capsule programme will decline with maintained coverage rates. Measuring the effectiveness of vitamin A capsules is much simpler than measuring the shift in a variety of fortified products or natural sources of vitamin A. Work is currently under way to measure the relative cost-effectiveness of different interventions. In the past, sustainability has not always been factored in, nor has the changing burden of costs (moving from donors to consumers).

The future

Several countries (Indonesia, India, and the Philippines) have made serious progress, at least at the national level, in eliminating xerophthalmia. All still have significant problems with vitamin A deficiency, as detected by serum retinol surveys. It is known that this must be having an impact on both morbidity and mortality of young children. However, it is likely that schoolchildren, adolescents, and women (especially pregnant and lactating women) will also show signs of vitamin A deficiency upon examination. The previous, largely successful approach has been to address children six months to six years of age (and it is implicit that this is the criterion being used to measure progress towards the end-of-decade goals). It is becoming clear that a broader, complementary life-cycle approach to vitamin A deficiency is now appropriate in many countries.

Over the last few years, there has been increasing emphasis on approaches such as fortifying foods with vitamin A and improving the diet of the population at risk. A mix of interventions will give governments the chance to shift from a subsidized vitamin A capsule programme to more sustainable, non-subsidized, consumer-funded vitamin A interventions. In an appreciable number of countries, supplementation with vitamin A will be a necessity for some years to come. Nevertheless, governments are seeking guidelines for phasing out the vitamin A capsule programme when fortification and other approaches emerge. Monitoring food-based strategies and fortification programmes is much more costly and perhaps not very cost-effective. Guidelines to assist governments in such transitions are a high priority.

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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."

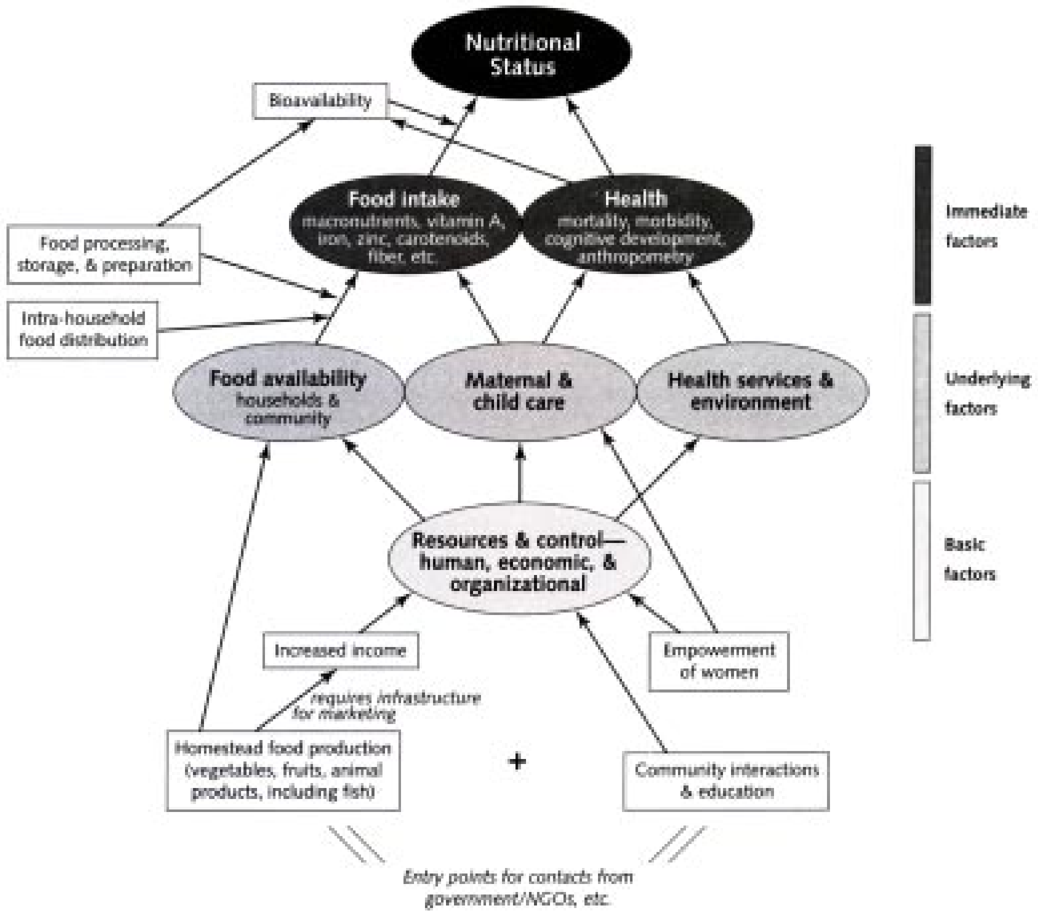

FIG. 1. Conceptual framework of causes of vitamin A deficiency (reprinted from ref. 5)

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.

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Appendix 12

Abstract from
XVII IVACG Meeting Report. The Nutrition Foundation 1996, Washington DC

Dietary Interventions

Does the production of dark green leafy vegetables and fruits play a role in the etiology of maternal night blindness, diarrhea and malnutrition in Bangladesh. Martin W. Bloem, Nasreen Huq, Jonathan Gorstein, Susan Burger, Tabibul Kahn, Nael Islam, Shawn Baker, Frances Davidson. (HKI, USAID)

Vitamin A deficiency is considered as a public health problem in Bangladesh, and a universal biannual distribution of high dose vitamin A capsules has been in place over the past two decades. Although this program is beneficial for preschool children, Bangladesh has been seeking more sustainable approaches for the entire population. Since 1993, Helen Keller International has been implementing a large scale home-gardening promotion project. In order to measure the potential impact of such a program, a community intervention trial has been integrated as part of the program design.

This study reports baseline data from a total of 7,382 women of reproductive age. In two logistic models, vitamin A intake above the median was significantly associated with indicators for homestead gardens after adjusting for various socioeconomic indicators.

Of the women studied, 3.2% (95% CI = 2.8, 3.6) reported being night blind at the time of the interview. Adjusted for house size, number of children under 6, age, agriculture land, size of the homestead, maternal education, family size, and oil consumption, vitamin A intake (> 400 RE; OR = 0.55, 95% CI = 0.41, 0.75; $P<0.0000$) was significantly associated with maternal night blindness. After adjusting for possible confounding factors, vitamin A intake above the median was significantly associated with a decreased risk of diarrhea (OR=0.62, 95% CI = 0.48-0.82; $p < 0.0000$), and a normal body mass index (BMI $\geq$ 18.5)(OR =1.15, 95% CI = 1.04, 1.27; $p=0.0074$).

This study provides evidence that dietary vitamin A intake is associated with home production of dark green leafy vegetables, and that relatively higher intake of vitamin A is associated with a decreased risk of maternal nightblindness, diarrhea and maternal chronic energy deficiency. Despite potential low bioavailability of beta-carotene in dark green leafy vegetables, promotion of production and consumption of these products seems to be valuable in those countries where there are no alternative sources with a higher bioavailability of vitamin A.

Appendix 13

Abstract from:
American Public Health Association 126th Annual Meeting Report, Novermber 15-18, Washington DC.

Bangladesh – XEROPTHALMIA FREE: COMBINED EFFECT OF VITAMIN A (VA) CAPSULE DISTRIBUTION AND HOME GARDENDING IN REDUCING VITAMIN A DEFICIENCY (VAD). L Kiess. MW Bloem, S dePee, A Hye, TA Khan, N Huq, Z Talukder, M. Haque, M. Ali, HKI/Bangladesh, HKI/Indonesia, Institute of Public Health Nutrition/Bangladesh, National Institute of Ophthalmology/Bangladesh.

VAD has been identified as a major public health problem in Bangladesh . The aim of our study was to assess the current prevalence of VAD among children and their mothers and to measure the effectiveness of the VA capsule and home gardening programs. In 1997 data were collected from 27,496 children aged 6-59 months from a random sample of 800 clusters in rural Bangladesh and analyzed using SPSS. The prevalence of night blindness in preschool children was 0.66 (95% CI 0.57-0.71), of bitot's spots 0.25 (95% CI 0.19-0.32), of active corneal lesions (X2A, X3A, X3B) of 0.02 (95% CI 0.0-0.4) and of corneal scars 0.06 (95% CI 0.04-0.10). Vitamin A capsule program, with a coverage of 81%, showed an effectiveness of 32-55% in preventing xerophthalmia (bitot's spots and night blindness respectively) in bivariate models and similar levels when adjusted for confounding factors (OR = 0.68, 95% CI 0.39-1.19; OR=0.55, 95% CI 0.39-0.78). For those children who did not receive a vitamin A capsule, the presence of a homestead garden was significantly protective against nightblindness. (OR = 0.43, 95% CI 0.23-0.80), controlling for age, socioeconomic status, and illness. In 1997 >80% of households had homestead gardens compared to <50% in the 1982. More than 6.5% of the women reported being nightblind during pregnancy and home gardening was protective (OR =0.43, 95% CI 0.24-0.77). Findings suggest that both the vitamin A capsule distribution program and homestead gardening may be critical for reducing the prevalence of clinical vitamin A deficiency among children and pregnant women in Bangladesh.

Appendix 14

The Strength of Linking Surveillance and Programs: Historical perspective of HKI's experience in homestead food production in Bangladesh, 1982-2001

The value of linking research, programs and policies, and monitoring and evaluation has been recognized by program managers and scientists for decades. However, there are still few experiences where research and programs have been linked in an iterative manner or where the cycle of Assessment, Analysis and Action has been used to support program decision-making in the field. The NGO Gardening and Nutrition Education Surveillance Project (NGNESP) in Bangladesh provides an excellent application of what UNICEF refers to as this 'Triple-A approach'. The NGNESP experience characterizes Helen Keller International's (HKI) well-established approach to the prevention of micronutrient deficiency and to poverty alleviation in the Asia-Pacific Region.

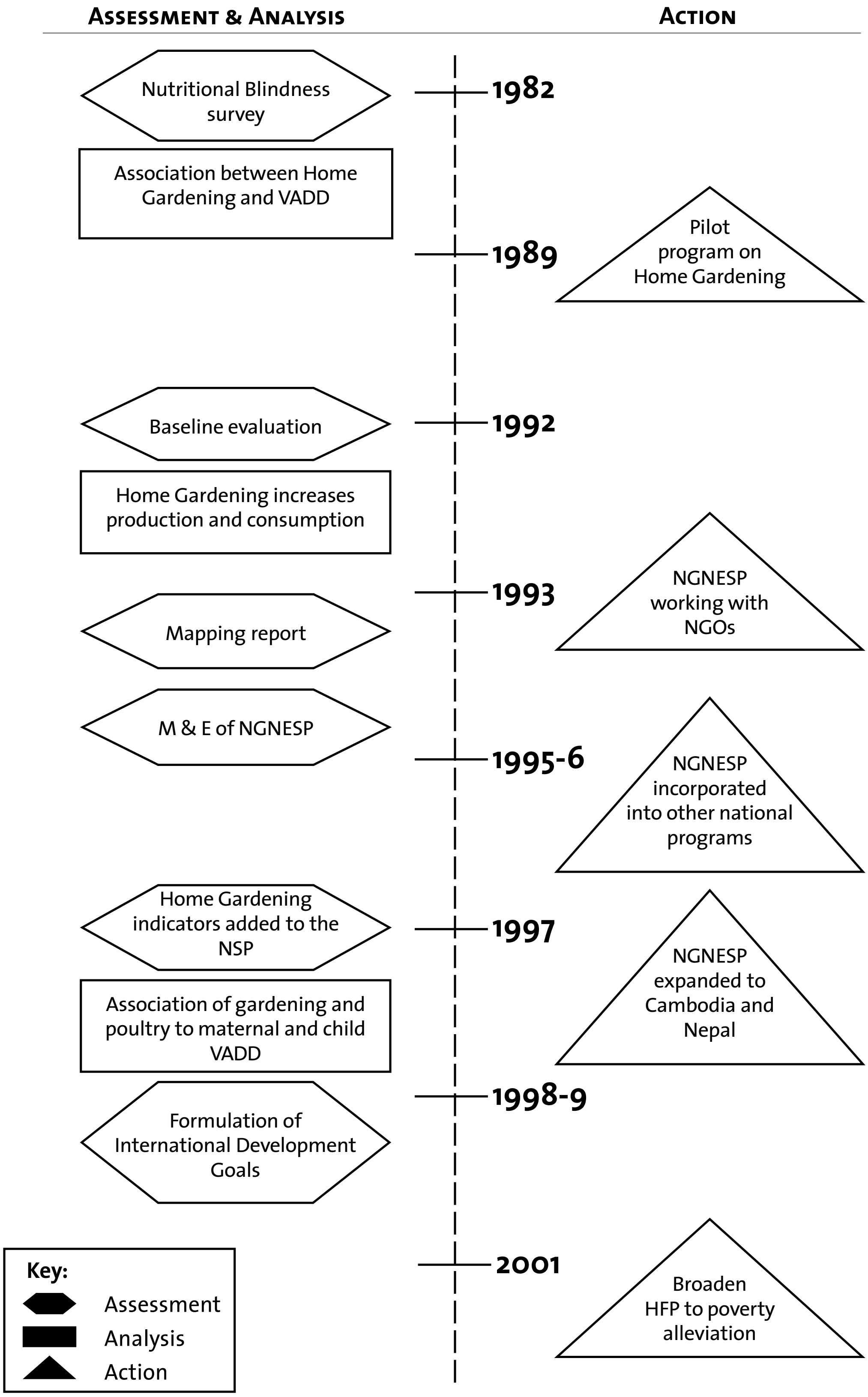
In 1982, HKI conducted a national survey to estimate the prevalence and determinants of nutritional blindness.[1] The survey showed that the presence of a home garden was associated with a lower risk of night blindness among preschool children.[1] Around this time, evidence of the child mortality impact of vitamin A deficiency disorders (even mild VADD) was becoming established.[2] Based on these survey findings, HKI initiated a pilot program in one subdistrict in 1989 to study gardening practices in rural Bangladesh and to explore the feasibility of improving the production and consumption of vitamin A-rich foods.

In 1992-93 HKI conducted an evaluation of the pilot program.[3,4] The evaluation showed that vegetable and fruit production and consumption increased among the program beneficiaries. Based on these findings, HKI developed a large-scale program to reduce vitamin A deficiency among poor households. In order to define program elements and an implementation framework, HKI also mapped the ongoing home gardening programs and the social and political environment within Bangladesh at that time [assessment]. The program design of NGNESP incorporated local non-governmental organizations (NGOs) and their role in community-based development, traditional gardening practices, and the role of women in decision-making. By working with the local NGOs, home gardening was made part of a 'menu' of community-based programs that included nonformal education, health, and microcredit. This integrated community approach provides households and individuals with freedoms, opportunities, and choices.

The NGNESP includes a monitoring and evaluation (M & E) system that provides information to monitor the program objectives, to manage program implementation and to fine-tune the program. The data from the M & E system are used to report on the performance of nurseries; on home garden practices, garden size and production; and on household and individual consumption, as well as on the performance of the program in different sites and among different partner NGOs. After each round of monitoring, findings are shared through program reports and bulletins. HKI has successfully used these findings to advocate the benefits of the program and, consequently, the NGNESP has been expanded to new areas with new local NGO partners over the past 8 years. This dissemination of the NGNESP experience has also stimulated the Department of Agriculture Extension and the Government of Bangladesh to replicate the program inside their agriculture and health programs.

In 1997, building on the experience with NGNESP, questions about home gardening practices, poultry and fisheries were incorporated into the Nutrition Surveillance Project (NSP) and the National Vitamin A Survey. These questions were added in order to assess the impact of homestead food production on a

Figure 1. Timeline of the 'Triple-A' cycle (Assessment, Analysis, Action) approach of HKI/APRO's Homestead Food Production program



national level, to monitor trends and patterns of production and consumption of plant and animal foods, and provide a comparison group for the NGNESP. Analysis of the vitamin A survey confirmed that home gardening lowered the risk of VADD among preschool children. In addition, the survey results suggested that the risk of night blindness was lowest among women and children in households with combined home gardening and poultry raising. These findings have been presented at international meetings to support the role of food and homestead food production. At the same time, HKI has used this experience and the momentum to start home gardening programs in Nepal and Cambodia.

Information from the M & E of the NGNESP and the surveys/surveillance systems has also been used for broader purposes. At the 1997 International Union of Nutritional Sciences meeting in Montreal, Canada, the experiences from HKI and other organizations formed the basis for the new conceptual model describing the direct and indirect mechanisms for the impacts of home gardening on nutritional status.[5,6] The data from NGNESP and the home food production indicators in the NSP are used to improve the national estimates of vegetable and fruit production. The experience has also stimulated 'thinking' on how to use surveillance and surveys to monitor national programs, and has provided insight to our understanding of determinants of food security – food availability, access and demand, particularly of high quality foods, such as animal foods, fruits and vegetables. This experience has been instrumental in helping to define and develop the food and nutrition links of the Food Insecurity Vulnerability Information Mapping Systems (FIVIMS). In addition, the experience in surveillance in Indonesia during the Asian economic crisis has stimulated 'thinking' about indicators. The initial findings that demonstrate how child anemia and maternal BMI reflect food accessibility may be useful for future monitoring of homestead food production, in the context of vitamin A, micronutrients and poverty alleviation.[7]

The experiences of the NGNESP have broadly contributed to and have been influenced by new thinking about poverty and development goals and priorities, the negative, long-lasting consequences of malnutrition and the co-existence of micronutrient deficiencies. This new thinking has simultaneously influenced how the NGNESP is promoted, how the benefits are monitored, and how households are most effectively reached regarding choices to improve their lives. The initial motivation for VADD programs – that improving VA status would reduce the risk of child mortality – is also part of the same motivation for promoting homestead food production to help achieve the International Development Goals, particularly the goals to reduce maternal and child mortality. The new perspective on poverty, however, recognizes how homestead food production can contribute to other goals, such as lowering poverty and increasing women's opportunities.

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- SANGKALPA
- SETU
- Shirashuni Humanitarian Enhance Territorial Unity (SHETU)
- Social Development Community (SDC)
- Society for Health Extension Development (SHED)
- SRIZONY
- The Coastal Association for Social Transformation Trust (COAST Trust)
- UDDIPAN
- UTTARAN
- Voluntary Association for Rural Development (VARD)
- Welfare Association for Village Environment (WAVE)
- Young Power in Social Action (YPSA)

Cambodia

- Adventist Development and Relief agency (ADRA)
- Chamran Cheat Khmer (CCK)
- Khmer Women's Cooperation for Development (KWCD)
- Partners for Development (PFD)
- Southeast Asian Outreach (SAO)
- Village Support Group (VSG)
- Women Services Organization (WOSO)

Nepal

- Center for Environmental and agriculture Policy Research, Extension and Development (CEAPRED)
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HKI Publications on Homestead Food Production

Since the start of the Home Gardening program in Bangladesh, HKI has generated a multitude of publications on the subject of Homestead Food Production in the Asia-Pacific region. The following is a comprehensive list of these publications.

Bangladesh

- Helen Keller International, Bangladesh (1991). *Vitamin A Home Gardening and Promotion of Consumption for Prevention of Nutritional Blindness. Evaluation Report-Pilot Project (October 1991)*. Dhaka, Helen Keller International.

- Helen Keller International, Bangladesh (1991). *Vitamin A Home Gardening and Promotion of Consumption for Prevention of Nutritional Blindness. Baseline Report (December 1991)*. Dhaka, Helen Keller International.

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Indonesia

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Key Conferences & Workshops

As one of the leading implementing agencies of homestead food production programs, HKI has often participated in conferences and workshops on the subject at the request of their organizers. Through these fora, HKI has shared key findings from its programs as well as helped to shape the future of food-based strategies to combat malnutrition and poverty. Below are some of the key conferences and meetings in which HKI has participated.

1991

- **Prevention of Vitamin A Deficiency and its Morbid Consequences through Community-Based Interventions.** XIV International Vitamin A Consultative Group (IVACG) Meeting, Guayaquil, Ecuador, June 1991.
  Sessions:
  - Management Issues
  - Availability and Consumption Issues
  - Information, Education and Communication Issues
    (Oral presentations and video session; for further information, abstracts can be found in the XIV IVACG Meeting Report, on pages 58, 64 and 72)

1993

- **Towards Comprehensive Programs to Reduce Vitamin A Deficiency.** XV IVACG Meeting, Arusha, Tanzania, March 1993.
  Sessions:
  - Dietary Behavior Poster Session
    (Summarized as short oral presentations in the plenary session; for further information, an abstract can be found in the XV IVACG Meeting Report, on page 132.)

1994

- **Two Decades of Progress: Linking Knowledge to Action.** XVI IVACG Meeting, Chiang Rai, Thailand, October 1994.
  Sessions:
  - Food-Based Interventions
    (Concurrent workshop; for further information, an abstract can be found in the XVI IVACG Meeting Report, on page 71.)
  - Home Gardens
    (Concurrent workshop and poster session; for further information, abstracts can be found in the XVI IVACG Meeting Report, on pages 76 and 92.)

1995

- **Bioavailability and bioconversion of carotenoids: Can foods rich in provitamin A carotenoids provide adequate vitamin A for human needs?** Workshop organized by The Micronutrient Initiative (MI) & Opportunities for Micronutrient Interventions (OMNI), April 1995.

- **Food-Based Approaches to Preventing Micronutrient Malnutrition: Setting an International Research Agenda.** Salt Lake City, USA, November 1995.

1996

- **Virtual Elimination of Vitamin A Deficiency: Obstacles and Solutions for the Year 2000.** XVII IVACG Meeting, Guatemala City, Guatemala, March 1996.
  Sessions:
  - Dietary Interventions
    (Concurrent session and poster session; for further information, abstracts can be found in the XVII IVACG Meeting Report, on pages 82 and 98.)

1997

- **Food Gardening for Nutrition Improvement: Potential contribution of home gardening to improve micronutrient status of vulnerable groups.** International Union of Nutritional Sciences (IUNS) Committee II/8, Wageningen, Netherlands, May 1997.

- **Bioavailability '97.** Wageningen, Netherlands, May 1997.

- **16th International Congress of Nutrition.** Montreal, Canada, July 1997.

- **Sustainable Control of Vitamin A Deficiency: Defining Progress Through Assessment, Surveillance, Evaluation.** XVIII IVACG Meeting, Cairo, Egypt, September 1997.
  Sessions:
  – Surveillance, Monitoring and Evaluation
  – Food-Based Interventions
  (Concurrent sessions; for further information, abstracts can be found in the XVIII IVACG Meeting Report, on pages 88, 100 and 106.)

1999

- **Vitamin A and Other Micronutrients: Biologic Interactions and Integrated Interventions.** XIX IVACG Meeting, Durban, South Africa, March 1999.
  Sessions:
  – Dietary Approaches to Sustainable Micronutrient Improvement
  – Methods and Outcomes of Vitamin A Program Evaluation
  (Concurrent sessions; for further information, abstracts can be found in the XIX IVACG Meeting Report, on pages 86, 101 and 102.)

- **Dietary Approaches to Vitamin A Deficiency.** International Union of Nutritional Sciences (IUNS)/United Nations University (UNU), Seoul, Korea, August 1999.

2000

- **Update Conference of the International Vitamin A Consultative Group (IVACG).** Annecy, France, Oct 2000.

- **Long-Term Food-Based Approach Towards Eliminating Vitamin A Deficiency in Africa.** National Research Programme for Nutritional Intervention, Medical Research Council, Cape Town, South Africa, November 2000.

2001

- **Years of Progress in Controlling Vitamin A Deficiency: Looking to the Future.** XX IVACG Meeting, Hanoi, Viet Nam, February 2001.
  Sessions:
  – Selected presentations on interventions
  (For further information, abstracts can be found in the XX IVACG Meeting Report, on pages 46 and 70.)

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