VITAMIN A: MOVING THE FOOD-BASED APPROACH FORWARD

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Abstract

Food-based approaches to combating vitamin A deficiency continue to be largely ignored by governments and donors. This may be partly because the way of viewing them has largely been informed by the community which supports supplementation. Food-based approaches may be perceived as competitive or distracting and are thus slandered, for example claiming they are unproven or even ineffective. To the contrary, it is the supplementation approach that fails to improve vitamin A status and is even lacking in proof of impact on young child mortality in real life settings. A wide variety of common and indigenous foods are proven effective in improving vitamin A status even in short-term trials. Food based approaches are complex to implement and to evaluate and take time to mature and exert impact. But unlike supplementation, they reach all members of the community, are safe for pregnant women, have no side effects, are sustainable, and confer a wide range of benefits in addition to improving vitamin A status. Food-based approaches are also often portrayed as being expensive, but this is only true from a "donor-centric" way of viewing costs. From the point of view of host countries, communities and families who grow vitamin A rich foods, the economic benefits are likely to outweigh the costs. The 1992 ICN called for the elimination of vitamin A deficiency. The urgency of this call may have provided an excuse for the rapid implementation of supplementation programs in over 100 countries while very few have implemented national food-based approaches. It is thus important that ICN 2 instead call for the replacement of supplementation programs with sustainable food-based approaches. It should call on countries to assign responsibility and funding to specific individuals or organizations who are then given benchmarks and are held accountable to meet them. Donors could greatly assist by funding simple dietary assessment and other components of national plans for making this shift.

Introduction

The prevalence of vitamin A deficiency (VAD) in developing countries among young children alone is estimated to be 30%, about 163 million cases (United Nations System Standing Committee on Nutrition 2010) and pregnant and lactating women are often affected as well, in some cases at alarmingly high levels (Ncube et al. 2001b). Yet global dietary changes, which receive little attention as part of large-scale programs focused on micronutrient malnutrition, are progressing such that nutrient dense traditional foods are declining and energy dense processed foods are increasing (Bermudez et al. 2008), a pattern which bodes ill for population status of vitamin A and other micronutrients, as well as for non-communicable diseases.

Food-based approaches to improve nutritional status, despite being the only sustainable way forward, and the way that has succeeded in eliminating micronutrient deficiencies as public health problems in industrialized and apparently some newly industrializing countries like Thailand (Wasantwisut, Chittchang and Sinawat 2000), continue to be largely ignored by international development donor agencies and the experts they work with. Governments are also giving little attention to these approaches. For example, even middle income countries have apparently so far failed to take concrete steps to promote increased consumption of vegetables and fruits by schoolchildren (Wijesinha-Bettoni et al. 2013), an easily accessible group. In Asia, which has perhaps the strongest intact culture of routinely eating a wide range of vegetables, consumption has in recent decades been low and stagnating in many countries (Ali and Tsou 1997).

As pointed out at a recent nutrition policy debate at Tufts University, “Food and nutrition challenges can no longer be seen as only single problems to be resolved by relatively simple solutions, such as providing vitamin A supplements to prevent deficiency and reduce child deaths by measles.” (Kennedy et al. 2011)

This paper argues that repeating the 1992 ICN’s call on decision-makers to implement all approaches to eliminate VAD will likely not be effective. A more assertive approach would call for ensuring that food based approaches to improving the micronutrient content of diets in low-income populations progressively become the universal norm. Donors currently funding supplementation approaches could assist by providing additional funding earmarked for food-based approaches, linked to assessment approaches that will allow supplementation to be phased out in geographical areas where it is no longer needed. Such an approach of gradually shifting from short-term to long-term approaches has long been called for (e.g. (Greiner 1993), (Bloem, de Pee and Darnton-Hill 1998)), has been achieved in the context of the phasing out of a national iodized oil capsule program in Tanzania (Peterson et al. 1999), has been described in detail (Greiner 2012), has already been planned for in some countries (Amoaful 2001) and in the Philippines a national nutrition education program has long had a stated objective to replace vitamin A capsules (Solon et al. 1996). For such a plan to be implemented, some government organization should be created or deputed, provided with a budget for implementing food-based approaches and for monitoring diet adequacy, and should be held accountable.

This paper provides arguments in support of such a proposed change. It summarizes the literature that has accrued since 1992 on the way supplementation has monopolized the vitamin A policy, program and donor support agendas, despite a lack of evidence of program impact; it describes food-based approaches, summarizing their benefits, evidence regarding how much impact high vitamin A foods can have on vitamin A status based on short-term trials, and the range of impacts that programs aiming to increase production and/or demand for vitamin A rich foods have had. Other background papers provide details on other food-based approaches for increasing intakes of vitamin A through food fortification, selective breeding, and biofortification.

Supplementation approaches have monopolized attention for decades

Soon after the 1992 ICN, in the most widely-cited meta-analysis of the original early vitamin A supplementation trials, Beaton et al (Beaton, Martorell and L'Abbe 1993) stated that the resulting decrease in young child mortality, an average of 23%, was not likely to be due to the effect of capsules but also could be expected with dietary approaches. A large prospective study found that mortality was about half the level in the quintile of children with the highest dietary intake of vitamin A (Fawzi et al. 1994). A presentation at the 1993 IVACG meeting called for donors to support universal supplementation programs only after ensuring that equal budgets were appropriated for dietary approaches and that a monitoring system for phasing out the "short-term" supplementation approach was in place (Greiner 1993). It was widely pointed out that no one program could succeed in reaching all vulnerable groups and thus that a combination of approaches was needed (de Pee and Bloem 2007). But certain powerful donor agencies and experts working with them apparently felt that it would be more effective to avoid potential distractions or competition for funds/attention by focusing attention and funding exclusively on periodic supplementation (megadosing of children with vitamin A capsules).

The original assumption that supplementation programs would open the way for other approaches has not been realized; instead supplementation programs have actively hindered the implementation of sustainable alternative approaches through several mechanisms (Latham 2010), (Kawarazuka and Béné 2011), (Greiner 2012). UNICEF stated that the success of supplementation programs and "high expectations" about fortification programs "reduce the interest in and resources available for the promotion of dietary diversification" (de Wagt 2001). The nutritional importance of access to a nutrient supplement or fortified food may be so exaggerated in the minds of community members as to result in less interest in nutritional improvement via food-based approaches (Miura, Kunii and Wakai 2003). A donor-driven approach, universal vitamin A capsule (VAC) distribution has gradually been spread to more and more countries where it is less and less needed, creating conflict among groups involved in nutrition policy formulation, especially in countries with a low burden of VAD (Pelletier et al. 2011).

Meanwhile, the purpose for implementing national supplementation programs shifted from prevention of severe VAD and blindness to prevention of young child deaths. Thus the fact that the supplementation approach fails to normalize vitamin A status, even for well-covered groups of children (van Jaarsveld et al. 2005), even after years of implementation (Ribaya-Mercado et al. 2007) and even for women given a dose soon after delivery (Rice et al. 1999) failed to influence policy-makers who assumed it was reducing young child mortality.

Yet the impact of the supplementation approach on reducing young child mortality has never been evaluated in real-life settings. Claims to the contrary (West, Klemm and Sommer 2010) have been based on studies that either utilized an estimated impact based on the initial clinical trial results or noted that mortality in national surveys declined, though other possible causes of that decline were not ruled out (Greiner 2010), (Mason, in press). By far the largest trial (n≈1 million), and the only one conducted recently, failed to find any impact on mortality (Menon et al. 2008). This has variously been explained by an assumption that the VAD present was too severe for a semiannual distribution to be adequate (Thurnham 2011) or that the only diseases found to have a link to vitamin A, measles and diarrhea, may no longer be as important as causes of young child mortality (Latham 2010) (Mason, in press).

Meanwhile, although proponents of the supplementation approach state that it is “entirely safe,” (Semba et al. 2010a), the fact is we do not yet understand the physiological effects of megadosing children with vitamin A (Prentice 2011), nor the mechanism by which it may in many cases protect against mortality (Benn et al. 2003), (Murphy and Allen 2003). Inflammation or infection rapidly reduces serum retinol. This promotes the immune system’s pro-inflammatory Th-1 responses. Vitamin A supplements may interfere with and block this response. Especially in children with normal vitamin A status, high dose supplements may lead to increasing respiratory tract infections or diarrhea (Grotto et al. 2003) and in HIV-positive women they may increase subclinical mastitis (Thurnham 2010). A Cochrane Review concluded “Low-dose vitamin A appears to have fewer side effects and at least equal benefit to a high dose of vitamin A.” (Chen et al. 2008).

Plant-based approaches are safe, even for pregnant women, at any dose that can be achieved. Promotion of increased consumption of animal sources, especially fish liver, do need to be careful to avoid excesses, especially in young children (Hayman and Dalziel 2012). It is not known whether large-scale supplementation programs are able to ensure that they are never given to pregnant women, in whom more than 10,000 is teratogenic (Rothman et al. 1995).

In summary, while supplementation advocates commonly claim that implementation of food-based approaches must await proof of their impact (De Pee and West 1996) (Smith 2000),(West et al. 2010), it is actually supplementation that is ineffective if the goal is normalization of vitamin A status, unproven at best if the goal is reducing young child mortality, and places recipients at risk of increased respiratory disease, particularly among those who are vitamin A replete.

The advantages of the food-based approach

Low-income populations tend to have monotonous diets with the majority of energy coming from starchy staple foods. Adding variety to their diets can be achieved through promoting increased production and consumption of a range of nutritious foods, many of which will contribute to improving vitamin A status. The purchase of manufactured nutrients benefits only a few large companies. Most of the foods used in food-based approaches to combat VAD are perishable and thus grown locally in the low income countries where the malnutrition exists. Some two-thirds of the people suffering from hunger living in farming or pastoral households in Africa and Asia (Borlaug 2007) and thus could be double beneficiaries. Food-based approaches promote self-sufficiency and food security while the other approaches tend to perpetuate dependency on external donor agencies.

Individual nutrient supplements do not contain as many nutrients, lack other health-promoting constituents, and have had such disappointing results in several contexts that in industrialized countries dietary improvement is now the preferred intervention (Lichtenstein Ah 2005) (Jacobs and Tapsell 2007). Food-based approaches controlled by the household such as home gardening may perform better at alleviating food insecurity than those dependent on government (Von Braun et al. 1993) and may even reduce levels of morbidity (English et al. 1997) (Laurie and Faber 2008) and growth retardation in young children (Makhotla and Hendriks 2004). Thus food-based approaches are the optimal approach to use in settings where multiple nutrients are deficient in diets of several groups in society.

The rationale for and multiple benefits derived from pursuing food-based approaches have been summarized in several excellent articles since the ICN ((Marsh 1998), (Ruel 2001), (Berti, Krasevec and FitzGerald 2004), (Wispelwey and Deckelbaum 2010), (Blasbalg, Wispelwey and Deckelbaum 2011), (Masset et al. 2011), and (Arimond et al. 2011)). Perhaps the most comprehensive documents on food-based approaches have been produced by FAO (FAO and ILSI 1997), (Thompson and Amoroso 2011), (Thompson and Herforth).Even small gardens can provide important quantities of key nutrients for a family (Marsh 1998). They can provide increased income (Ruel 2001) food and employment during lean seasons and provide protection against external shocks that disrupt local markets (United Nations Development Programme 1996). Large-scale programs have observed that benefits expand passively beyond the intervention areas to nearby communities (Greiner and Mitra 1995), (Talukder et al. 2000), (Faber et al. 2011).

Children with low vitamin A intakes tend to come from families with low socioeconomic status, who are also the ones least likely to receive VAC (Semba et al. 2010b). The increased income achieved via household gardening was found to be used mainly for the purchase of food (Talukder et al. 2000). Increased income among women (Brun, Reynaud and Chevassusagnes 1989) (who tend to take over gardening projects, even if initially targeted to men) and even women’s decision-making power within the household (Bushamuka et al. 2005) are often likely to be major benefits. Household gardens not only provide increased access to a wider variety of nutritious foods to low-income households, they also are utilized to grow plants used in traditional medicine (Ijinu et al. 2011).

Food sources of vitamin A

In general, a wide range of foods containing either preformed or provitamin A are widely available and acceptable to nearly everyone in all countries. An excellent listing of the most useful ones in most settings is provided by (Rodriguez Amaya 1997).

Animal-source foods

The most commonly available animal-source foods that contain significant quantities of the form of vitamin A that is functional in the body, retinol, include:

- Cream, butter and non-skim milk
- Eggs
- Liver
- Fish

Retinol is thus available only in certain animal-source foods. The most common animal source among many low-income groups is small, wild, indigenous fish, which may vary from <100 to >2500 RE/100g raw edible portions (Roos, Islam and Thilsted 2003). Such small species make up 50–80% of all fish eaten during the fish production season in rural Bangladesh and Cambodia (Roos et al. 2007). In larger fish the entrails and head are usually removed and the remaining portions are low in retinol. However, larger varieties are more likely to be sold (Thompson et al. 2000). In the best season, fish provides up to 40% of household vitamin A needs in Bangladesh (Roos et al. 2003).

Eggs (ref) and milk (Persson et al. 1999) can also provide a meaningful source of vitamin A in the diets of young children, even in some low income settings. Because vitamin A levels in liver are so high, small amounts can be useful at a reasonable cost (ref).

Although meat and some fish are poor sources of vitamin A, they usually add fat to the diet, which, in the low-fat diets often consumed by people in low-income settings, is likely to increase absorption of carotenes (Yonekura and Nagao 2007). They can have another indirect positive impact on vitamin A status. Iron deficiency may contribute to poor vitamin A status (Bloem 1995), and meat and fish provide highly absorbable heme iron and also enhance iron absorption from plant sources. Because of their high value, sales of animal-source foods may also result in increased purchase of fruits and vegetables (Ayele and Peacock 2003).

Although expensive, preformed retinol from animal sources is highly bioavailable. Thus, relatively small quantities of animal-source foods can have a large impact on vitamin A status. In Mexico, animal-source foods (not counting breast milk) provided 18% of the estimated average requirement (EAR) of vitamin A for children 7-11 months old and 43% for those 12-23 months old and in Peru, 12% for children 7-11 months old (Pachon et al. 2007). A case-control study in Nepal found that consumption of preformed retinol was associated with less risk of xerophthalmia (Shankar et al. 1996).

It is commonly found that traditional beliefs also limit the extent to which animal-source foods are given to infants. Given their greater susceptibility to infection from oral intake of pathogens, such restrictiveness in the lowest income settings may be wise; any approach to increase consumption of animal-source foods in infants must give attention to assuring good household hygiene and food safety practices. Such risks decrease as children grow older and parents typically share any such foods the family can afford with older toddlers.

Breast milk

Breast milk is the most important animal-source food source of vitamin A for infants and young children in low-income settings and achieving optimal breastfeeding practices ought to be the first priority of food-based approaches. Too often agricultural-related programs and policies demur from this, assuming that breastfeeding is an issue that should be exclusively dealt with by the health sector. Breast milk can provide substantial amounts of vitamin A in toddlers in areas like South Asia where breastfeeding is commonly practiced for three years or longer (Persson et al. 1998) (Greiner, Gebre-Medhin and Persson 1999). The amounts in breast milk depend on the mother’s vitamin A status, which has been found to be quite low in some rural areas of Africa (Ncube et al. 2001b), (Ettyang et al. 2004). Food-based approaches may increase vitamin A levels in breast milk, even while having little impact on the mother's own vitamin A status (Lietz et al. 2001).While the vitamin A level in breast milk is normally able to maintain vitamin A status in infants even when inadequate to build their stores, clearly food-based approaches should give high priority to improving the diets of pregnant and lactating women.

In some cultures some colostrum, an especially rich source of vitamin A, is discarded on the false assumption that it is harmful; in India, about half of the mothers attempt to discard it (Vijayaraghavan 2002). Even more commonly, some colostrum may be displaced by prelacteal feeds, widely given in many countries in the false belief that the infant needs more food than the relatively small amounts of colostrum available can alone provide (ref). Exclusive breastfeeding, though recommended for 6 mo, is often not practiced for more than 2-3 months. In most low-income settings, breast milk nevertheless is protective enough that infant vitamin A status is better than that of toddlers. However, where supplementation begins at an early age with foods low in vitamin A, younger infants may have lower vitamin A status, as in China (Jiang et al. 2008), and severe VAD may then appear even in young infants (Agne-Djigo et al. 2012).

Plant foods

Whereas in industrialized countries only about 35% of dietary vitamin A comes from plant sources (Weber and Grune 2012), in developing countries, plants typically provides over 80% of vitamin A (Codjia 2001), (de Pee et al. 1998a), reaching 95% in Bangladesh (Bouis and Novenario-Reese 1997) and over 1/3 of this is from indigenous varieties (Chadha et al. 2011).

While about 50 carotenoids could in theory be vitamin A precursors, vitamin A activity has been measured for only about 15 of them. By far the one with the greatest provitamin A effect is beta-carotene, though a couple others have about half its activity. Alpha carotene and beta cryptoxanthin may be more bioavailable (Burri, Chang and Neidlinger

2011). And in addition the majority of the provitamin A content of certain foods such as papaya may be from other carotenoids (Rodriguez Amaya 1997).

Carotenoids are much less well absorbed than retinol and once absorbed must be converted to retinol in the body. The conversion factor used by most researchers in estimating the retinol equivalency of carotenoids was 6:1 until 2000, when the US Institute of Medicine changed its estimate to 12:1 (IOM 2000). A higher value is probably more accurate for the diets of most low-income people (Shetty 2009). Using intrinsically labeled beta carotene, the conversion factor found for spinach was about 21 and for carrots was around 15 (Tang et al. 2005).

The retinol precursor carotenoids (carotenes and xanthophylls) tend to be available in increasingly large quantities in plant foods as colors intensify. Colorful plant foods are also important sources of other nutrients and other health-promoting constituents, including some that appear to reduce risks for cancer and other chronic disease risks.

The commonly available foods that contain significant quantities of provitamin A include:

- Oils that are orange or red in color such as red palm oil (other low-cost oils from for example oil seeds, can also contribute to vitamin A nutriture by increasing absorption of carotenoids)
- Non-citrus fruits that are yellow, orange or red in color (for bananas, mainly the ones that are dark yellow, orange or red) (Englberger et al. 2003)
- Root crops, squash and pumpkin that are deep yellow or orange
- Most green vegetables, with very high levels in some dark green leafy vegetables (DGVL)

A number of other less common foods contain significant amounts of carotenoids. Guidelines for using ethnographic approaches to locating which ones are available in any given community (for example in order to promote their increased use) are available online (Blum, Pelto and Kuhnlein 1997).

Red palm oil has a 5.7:1 retinol equivalency (You, Parker and Swanson 2002). Other less common high-carotene oils include the oil of the gac fruit, indigenous to Southeast Asia. It can be easily pressed at household level, and was easily accepted by Vietnamese families who obtained 5mg $\beta-\mathrm{carotene}/\mathrm{d}$ by consuming only 2ml/d on average (Vuong and King 2003). Spirulina, a cultivated algae, is not only high in carotene, its conversion factor is only 4.5:1 RE (Wang, Wang and Wang 2008).

The next most effective plant foods for improving vitamin A status are certain fruits, the most common of which are mango (Drammeh et al. 2002) and papaya. Though less commonly consumed, palm fruits have a higher carotenoid content (Rodriguez Amaya 1997) and there are many tropical fruits, often growing wild, such as pandanus (Englberger et al. 2008) which can be extremely high in carotenoids. Some melons may have a relatively high carotenoid content. While fruits often have lower levels of carotenoids than some vegetables, their carotenoids are much better absorbed (de Pee et al. 1998c) and they have the major advantage of being easily accepted by young children.

Orange-fleshed sweet potato (Low et al. 2007) and yellow varieties of giant taro (Englberger et al. 2008) are quite high in carotenoids. In these tubers (as in fruits), the beta-carotene is in tiny oil droplets in chromoplasts and thus better absorbed than carotene in most vegetables (Castenmiller and West 1998).

Orange fleshed sweet potato enjoys high consumer acceptability (Tomlins et al. 2007), is relatively easy to cultivate during most of the year, is vegetatively propagated (saving the cost of seed, often the greatest capital outlay for home gardens (Faber and van Jaarsveld 2007)), and relatively drought resistant. It is also well-accepted by young children.

Many types of yellow squash and yellow or orange pumpkin are also significant sources of provitamin A. They are easy to produce, have a long shelf life, and are widely distributed around the world. Again, coloration and thus carotene content varies widely among different varieties and like for tubers, in many countries it is the pale varieties that are the most popular.

Wild or low-cost DGLVs, are the main provitamin A sources in many low-income communities and the main ones promoted in many food-based programs. Moringa (drumstick tree) is receiving increasing attention as an especially valuable tree leaf extremely low in cost and available at no cost in much of Africa (Babu 2000).

Very little attention has been given to the fact that certain varieties of existing staple foods, higher in carotene than those most commonly grown today (including wheat, maize, potato, sorghum and sweet potato), could probably eradicate VAD (Graham and Rosser 2000). Certainly highly colored banana and plantain varieties could routinely provide large quantities of provitamin A (Fungo and Pillay 2011) (Englberger 2001) (Englberger et al. 2003). It has been estimated that about half of normal vitamin A requirements for women could be met by consumption at common levels of any of 10 yellow-colored banana varieties available in Australia (Englberger et al. 2006). Even cassava has varieties with yellow flesh (Gibson et al. 2000). Because staple foods are eaten in such large quantities daily by everyone in the family, finding ways to increase production and consumption of varieties higher in provitamin A deserves much higher priority than it has received so far among the food-based approaches.

The carotenoids in most fruits, peppers and tomatoes increase with ripening. During post-harvest storage, carotenoid levels continue to increase in most intact fruits, but decline, sometimes rapidly and substantially, in peppers, leeks and DGLVs (Rodriguez Amaya 1997). Carotenoids in green beans and broccoli show no significant changes under typical post-harvest retail marketing conditions (Wu, Perry and Klein 1992).

All of these foods can be cultivated and some (especially wild fruits and berries, the leaves of wild plants, and fish and small animals) can be foraged and thus cost no money. Although wild foods tend to have higher levels of nutrients, including carotenoids, than cultivated ones

(Kobori and Rodriguez Amaya 2008), their use has been inadequately promoted and they remain underutilized (Vuong 2000). Forest lands, wetlands and even weeds in cultivated land often provide access to carotenoid rich foods not available in markets, some of which are available off-season.

While a higher intake of animal-source foods would in theory improve vitamin A status, this is often not economically feasible. In one study in Peru the opposite occurred because meat (a poor source) displaced plant sources in the diet (Carrasco Sanez et al. 1998). Unlike plant foods, animal-source food use declines at times of economic difficulty (West and Mehra 2010). High plant intakes are also consistent with global needs to reduce overweight and non-communicable diseases.

It is often assumed that young children will not eat DGLV. However, they accept it once they have tasted it a number of times. One study in Bangladesh found that 89% of children 6 months to 3 yr old liked them (Rahman et al. 1993).

The impact of foods on vitamin A status

Conventional fortification, biofortification, and home fortification simulate the way natural foods provide relatively small doses of vitamin A relatively often and studying their impact is a simpler task for researchers for several reasons, including controlling the dose. Mason (in press) has reviewed the evidence and concludes that they indeed can have an impact on vitamin A status.

Making the case that natural foods alone can normalize vitamin A status for low-income populations is more difficult for several reasons. First, in low-income populations there has been very little research. Second, what has been done may have measured impact over too short a period of time to have any realistic relationship with the way vitamin A nutriture works with respect to the daily diet. Third, the methods used in most existing research are too weak to allow for decisive conclusions.

Table 1 examines the evidence that has accumulated since 1992 regarding changes in serum beta-carotene and serum retinol of randomized trials of foods. The addition of fat or deworming in advance, when included, are noted because of their potential importance in carotenoid absorption.

Table 1. Impact of food supplements on serum $\beta-$carotene and/or serum retinol (studies published after 1992)

Reference	**Food**	**Quantity/day**	**No. of days**	**participants**	**N**	**Impact on serum $\beta-$carotene in $\frac{\mu}{mol}/L$**	**Impact on Serum retinol in $\frac{\mu}{mol}/L$**
(Ncube et al. 2001a)	Pureed papaya	650g + `10g fat	60	Women breastfeeding babies 2-12 mo old	49		Net[a] 0.2; Net reduction in VAD[b] 13%[c]
(Ncube et al. 2001a)	Grated carrots	100g + ` 10g fat	60	Women breastfeeding babies 2-12 mo old	49		Net 0.3; Net reduction in VAD 15%[c]
(Persson et al. 2001a)	DGLV[d]	14g fat (also for control) +200g, providing ~1.5mg $\beta-$carotene	6d/wk for 6 wk	Dewormed school children	37	Net 0.24	Net 0.083
(Persson et al. 2001a)	Pale orange pumpkin	14g fat (also for control)+100g DGLV (4 kinds on rotating basis) providing about 3.5-4mg $\beta-$carotene	6d/wk for 6 wk	Dewormed school children	36	Net 0.12	Net 0.047
(van Jaarsveld et al. 2005)	Resisto (orange) sweet potato	125g providing 1031 RAE[e]/d, 2.5 times the RDA[f] (conversion factor used was 12:1). Controls received a white variety.	53 d over 10.6 wk	Dewormed school children aged 5-10	89+89		Intervention effect 0.034

(Takyi 1999)	DGLV + 20g fat	Provided 400 RE	90	Preschool children	85		Net 0.13
"	DGLV	Provided 400 RE	"	"	79		Net 0.12
"	DGLV+ 20g fat	Provided 400 RE+ deworming	"	"	84		Net 0.20
(Lietz et al. 2001)	Sunflower oil	12g/d advised and provided	6 mo	Women in last trimester and 3 mo postpartum	30	Net 0.05; Breast milk, mo 1-3, Net 0.02	Net 0.15; Breast milk, mo 1-3, Net 7.64
"	Red palm oil	12g/d advised and provided	6 mo	Women in last trimester and 3 mo postpartum	30	Net 0.8; Breast milk, mo 1-3, Net 0.28	Net 0.01; Breast milk, mo 1-3, Net 10.21
(Haskell et al. 2004)	Cooked pureed sweet potato	80g twice a day, total 4.5 mg beta-carotene	60d	Men	14	Net 0.21	Net 0.23
(Haskell et al. 2004)	Cooked pureed Indian spinach	75 g twice a day, total 4.5 mg beta-carotene	60d	Men	14	Net 0.27	Net 0.34
(Jamil et al. 2012)	Boiled orange sweet	64 g twice a day, total 6-7 mg beta-carotene	6 d/w for 10 wk	Non-pregnant, non-lactating women 18-45 y/o	30	Net ~ 0.11	Net ~ -0.08

	potato						
(Jamil et al. 2012)	Boiled orange sweet potato fried in 5 g oil	64 g twice a day, total 6-7 mg beta-carotene	6 d/w for 10 wk	Non-pregnant, non-lactating women 18-45 y/o	30	Net ~ 0.27	Net -0.06
(Drammeh et al. 2002)	mango	75g dried mango providing 148 μg beta – carotene	5d/w for 4 mo	Children 2-7 yr	45	Net 0.27	Net 0.03
(Drammeh et al. 2002)	Mango and fat	75g dried mango + 5g sunflower oil	5d/w for 4 mo	Children 2-7 yr	44	Net 0.21	Net 0.02
(Tang et al. 1999)	Green-yellow vegetables	235g/d	5d/w for 10 w	Kindergarten children	22	Net 0.27	Net 0.23 ($p<0.02$)
(Manorama, Sarita and Rukmini 1997)	Red palm oil snack	Contains the RDA, 2.4mg $\boldsymbol{\beta-\text{carotene}}$	Daily for 2 mo	Children 7-9 yr	12		1.03 (no negative control)
(Manorama et al.	Red palm oil snack	Contains the RDA, 2.4mg $\boldsymbol{\beta-\text{carotene}}$	Daily for 2	Children 7-12 yr w VAD	18		0.90 (no negative control)

1997)			mo				
(Manorama et al. 1997)	Red palm oil snack	4g red palm oil in a snack containing 50,000 IU vitamin A	Daily for 1 mo	Children 7-9 yr	12		0.52 (no negative control)
(Manorama et al. 1997)	Red palm oil snack	8g red palm oil in a snack containing 100,000 IU vitamin A	Daily for 1 mo	Children 7-9 yr	12		1.19 (no negative control)
(Sivan et al. 2002)	Red palm oil in meal	5ml = 400 RE	6d/wk for 7 mo	Preschool children	37	~0.2 net compared to control given 5ml peanut oil	~0.8 net compared to control given 5ml peanut oil
(Sivan et al. 2002)	Red palm oil in meal	10 ml = 800 RE	6d/wk for 7 mo	Preschool children	26	~0.5 net compared to control given 10ml peanut oil	~0.4 net compared to control given 10ml peanut oil
(Siekmann et al. 2003)	milk	200-250 ml/d	1 yr	School children	115		Net 0.04 (increase was 0.35 but control also increased; meat suppl resulted in 0.27, less than control)
(de Pee et al. 1995a)	High carotene vegetables	100-150g stir-fried vegetables w 3.5 mg beta carotene	Daily for 12 wk	Breastfeeding women, nearly all infected with at least 2 parasites	57,	Net 0.05	Net 0.04 (breastmilk retinol -0.20)
(Ribaya-Mercado	Orange fruits and	1 meal and two snacks daily providing 12 mg beta	5d/wk for 12	Dewormed 7-13 y/o school children	27		0.38 (no control)

et al. 2000)	vegetables	carotene	wk				
(Ribaya-Mercado et al. 2000)	No food	Two snacks with no vitamin A	5d/wk for 12 wk	Dewormed 7-13 y/o school children	25		0.20 (no control)
(de Pee et al. 1998c)	Orange fruits	2 meals/d providing 535 RE	6d/wk for 9 wk	Anemic children 7-12 y/o, most helminth-infected	49	Net 0.49	Net 0.07
(de Pee et al. 1998c)	DGLV	2 meals/d providing 684 RE	6d/wk for 9 wk	Anemic children 7-12 y/o, most helminth-infected	45	Net 0.13	Net 0.12
Anemic children 7-12 y/o	Retinol-rich animal-source food	2 meals/d providing 556 RE	6d/wk for 9 wk	Anemic children 7-12 y/o, most helminth-infected	48	Net 0.03	Net 0.23
(Mahapatra and Manorama 1997)	Red palm oil	4g in a snack (equivalent to 25,000 IU)	Daily for 15 d	Children with VAD, 7-9 y/o	12		0.52 (no control); 0.12, 3 mo after supplementation
(Mahapatra and Manoram	Red palm oil	8g in a snack (equivalent to 50,000 IU)	Daily for 15 d	Children with VAD, 7-9 y/o	12		1.19 (no control); 0.37, 3 mo after supplementation

a 1997)							
(Vuong, Dueker and Murphy 2002)	Xoi gac fruit	3.5 mg beta carotene, 85 mg total carotenoids	Daily for 30 days	Children 31-70 mo old	59	Net 2.0	Net 0.03
(Bulux et al. 1994)	carrot	50g carrot containing 6 mg beta carotene + 33g veg fat;	Daily for 20 d	Children 7-12 y/o, the majority infected by tricharis or ascaris	17	NS, 1/5 as large as response to equivalent doses of pure beta carotene	NS (nor was there are a response to suppl w retinol or pure beta carotene)
(Haskell et al. 2005)	Goat liver	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	52	-.03 (no control)	~0.3 (no control)
(Haskell et al. 2005)	Amaranth leaves	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	51	0.05 (no control)	No change (no control)
(Haskell et al. 2005)	carrots	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	53	0.12 (no control)	~0.05 (no control)
(Canfield and Kaminsky 2000)	Red palm oil	6 doses, each containing 15 mg beta-carotene total	10 d	Lactating women (w children 1-24 mo)	32	0.35; 53.1 in breast milk (no controls)	0.13 (in infant; no control)
(Canfield	Red palm	6 doses, each containing	10 d	Lactating women	32	Net 0.3 (infant 0.18	Net 0.02 (infant net

et al. 2001)	oil	15 mg beta-carotene total		(w children 1-24 mo)		but placebo was the same so net 0)	0.06)
(Radhika et al. 2003)	Red palm oil	2.4 mg beta-carotene	8 wk	Women at 24-26 wk pregnancy at baseline	67		0.3 (control received 8ml/d peanut oil and increased 0.14; thus net increase was 0.16); Newborn cord SR net 0.11
(Törrönen et al. 1996)	Raw carrots	120g/d providing 12 mg beta carotene	3 and 6 wk	Healthy non-smoking women 20-53 y/o	13	187mcg/l and 169mcg/l (no control)	
(Törrönen et al. 1996)	Carrot juice	1 dl/d providing 12 mg beta carotene	3 and 6 wk	Healthy non-smoking women 20-53 y/o	13	167mcg/l and 288mcg/l (no control)	
(Jalal et al. 1998a)	fat + deworming	15g fat/d + deworming 1 wk previously	21 d	Children 3-6 y/o	38		Net 0.15
(Jalal et al. 1998a)	Sweet potato and veg's	Enough to supply 750 RE/d	21d	Children 3-6 y/o	39		Net 0.2
(Jalal et al. 1998b)	Deworming +food	Deworming 1 wk in advance plus 750 RE food/d	21d	Children 3-6 y/o	38		Net 0.25
(Jalal et	Fat +	15g fat+750 RE food/d	21d	Children 3-6 y/o	39		Net 0.35

al. 1998b)	food						
(Jalal et al. 1998b)	Fat+deworming +food	15g fat, deworming and 750 RE/d food	21d	Children 3-6 y/o	40		Net 0.32
(van Stuijvenberg, Benad and S. 2000)	Red palm oil	Biscuits fortified with red palm oil providing 34% RDA	3 mo	Primary school children	133		Net 2.6mg/dl
(Khan et al. 2007)	Orange or yellow fruit	4.8 mg beta-carotene	6d/wk for 10 wk	Lactating women	69	Net 0.30; breast milk net 0.24	Net 0.14, breast milk net 1.39
(Khan et al. 2007)	DGLV	5 mg beta-carotene/d	6d/wk for 10 wk	Lactating women	73	Net 0.16; breast milk net 0.13	Net 0.11, breast milk net 1.33
(Khan et al. 2007)	Animal-source foods	610 RE+ 0.6 mg beta-carotene	6d/wk for 10 wk	Lactating women	70	Net 0.05; breast milk net 0.06	Net 0.27; breast milk net 1.92
(Haskell et al. 2004)	Spinach	60g/d of Pureed spinach providing 750 RE	60 d	men	14	Net 0.24	Net 0.34
(Haskell et al.	Sweet potatoes	60g/d of Pureed sweet potato providing 750 RE	60 d	men	14	Net 0.21	Net 0.23

2004)							
(Kongsbak, Thilsted and Wahed 2008)	Mole fish	50g fish curry providing 600 RAE	6d/wk for 9 wk	Children 3-7 yr	61	RBP Net -0.02	Net -0.05
(Davys et al. 2011)	Leaf concentrate	Unspecified amount incorporated into diet	18 mo	Children 2-5 yr/o	unspecified		Net 0.54

a. When papers did not calculate a difference between changes that took place in the intervention and control groups, the mean of the change in control group values was subtracted from the mean of the change in the intervention group and this is referred to as the "net" value. Values presented represent increases unless preceded by a – sign.

b. VAD="vitamin A deficiency," defined as serum retinol < 70 $\frac{\mu}{\mathrm{mol}}/\mathrm{L}$

c. These changes were almost as great as those obtained by providing capsules containing 6mg $\beta - \mathrm{carotene/day}$

d. DGLV=dark green leafy vegetables

e. RAE=retinol activity equivalents

f. RDA=recommended daily allowance

Generally speaking, supplementation programs utilizing unfortified foods could not be expected to alone normalize vitamin A status in deficient individuals during a short period of time with the possible exception of red palm oil. 8g given in weekly doses for 12 weeks would in theory achieve the same impact as the usual 200,000 IU megadose supplements (Solomons and Orozco 2003).

It should be noted that improvements in vitamin A status are difficult to measure; various body compartments interact dynamically (Fujita et al. 2011), and changes in serum retinol values may be misleading. In one study in lactating women, red palm oil supplementation substantially increased the alpha and beta carotene levels of breast milk, but not the maternal serum retinol (SR) levels (Lietz and Henry 1999). In one feeding trial (Jamil et al. 2012), SR actually decreased (though this was not statistically significant) in the groups fed substantial quantities of beta-carotene rich orange sweet potato. However, the total body pool of vitamin A was marginally greater in the group fed fried sweet potato (who thus also received 5 g fat with each portion) than in the group fed white sweet potato. Haskell et al (Haskell et al. 2005) found that feeding amaranth leaves to nightblind Nepali women eliminated symptoms as well and as rapidly as high dose vitamin A or goat liver, but in the amaranth group SR failed to respond as well.

There is a large individual variation in response to supplementation with beta carotene or foods rich in it, even in carefully controlled studies (Törrönen et al. 1996). Bulux et al (Bulux et al. 1994) obtained a very small response in plasma beta carotene 8 and 14 hours after the ad libitum consumption of carrots in Guatemalan schoolchildren, with baseline levels having only a small influence. The quantities of high-carotene foods needed to maintain vitamin A status may also vary widely. For example, one study estimated that one cup a day of boiled, mashed sweet potato would meet the vitamin A needs of toddlers (Hagenimana et al. 2001) and another estimated that only 0.02 to 0.13 cups would be needed for three year old children with marginal vitamin A deficiency (Burri 2011).

Most importantly, very few trials have taken into account the baseline vitamin A status of the subjects in such research. A subgroup analysis of one food supplementation trial (done only in response to criticism of the study) showed that retinol responded three times more in serum and ten times more in breast milk in the group with low vitamin A status at baseline (De Pee et al. 1995b).

In spite of this common pattern of widespread biological variability, it is clear that provision of adequate quantities of foods rich in retinol or provitamin A can prevent VAD, and indeed, in the case of red palm oil, could be used to treat it (Mahapatra and Manorama 1997).

The potential components of food-based programs

In high income settings, food clearly can provide adequate vitamin A status. In North America (where several common foods are fortified with vitamin A) and in Europe (where few if any commonly consumed foods are fortified) VAD is rare although universal supplementation programs do not exist. Higher intake of vitamin A rich food is clearly associated with SR in large-scale studies (de Pee et al. 1998a), (Kidala, Greiner and Gebre-Medhin 2000). Food-based approaches thus CAN work when they result in sustainable increases in intake of vitamin A rich food, if given enough time.

There is also little doubt that large increases in income will greatly reduce or eliminate VAD. However, at levels realistic in most settings, increases in income have very little impact on vitamin A status (Ecker and Qaim 2010). This may be because many of the foods consumed by the very poorest groups (wild vegetable leaves and fruits; breast milk) are much higher in vitamin A than the foods that replace them as incomes increase marginally (Bloem et al. 1996).

Thus an intentional promotion of increased production and consumption vitamin A rich foods is usually required. An increase in diversity alone tends to increase the intake of both energy and nutrients (Deckelbaum et al. 2006). However, some research suggests that diets must include retinol-rich animal-source foods or household gardens must include high carotene plant foods to be effective (Shankar et al. 1998).

The most commonly implemented food based approaches include the following:

- Behavior change efforts to increase consumption of foods rich in vitamin A or provitamin A (nutrition education, social marketing, etc), focusing on high-impact foods available but underutilized by vulnerable groups.
- Home food provisioning (kitchen, household, urban or community gardening; small animal production; fishing—especially for small fish or aquaculture; raising milk-producing animals)
- Food and price policies directly related to relevant foods (theoretically important, but impacts on vitamin A intakes or absorption tend to be indirect, unintentional outcomes), the practices of agricultural research and extension agencies (supporting production of relevant foods), policies and programs that affect water availability, policies and programs that affect the availability of and access to markets for relevant foods.
- Food and nutrient preservation through improved processing, preservation, storage and food preparation methods, including adding fat to the diet.
- Public health measures, particularly measures to reduce childhood morbidity, especially measles vaccination, will improve vitamin A status indirectly; deworming will increase absorption of carotenoids
- Breastfeeding protection, support, normalization and promotion

- Improving complementary feeding of infants and young children (while food-based approaches are possible (Badifu et al. 2000), (Mensah and Tomkins 2003), (Amagloh et al. 2012), (Kunyanga et al. 2012) they have received little evaluation, it is difficult to avoid a loss of vitamin A status through the breast milk that complementary foods displace (Dewey and Brown 2003), and thus this issue is not a focus of this paper)
- Breeding for plants high in provitamin A (covered in another background paper)
- Conventional food fortification (covered in another background paper)
- Biofortification (covered in another background paper)

Designing food-based approaches

Due to their complexity, food-based approaches tend to require time, patience, and exploratory research to develop approaches that are effective in local contexts. They must be designed based on a community assessment (Nana et al. 2005) with involvement of the local population and local agricultural or agronomy experts. They must identify the major limitations in the local diet and in locally available and affordable sources of vitamin A and constraints that have prevented improvements being made in the past. See (Gillespie and Mason 1994), (Food and Agriculture Organization of the United Nations and International Life Sciences Institute 1997), and (Underwood and Smitasiri 1999) for more details regarding the planning process.

In low-income countries, the cost of the most affordable sources of vitamin A is likely to be the single most important issue to address. In Bangladesh, for example, efforts in the agricultural sector in the 1980s and 1990s led to a 40% inflation-adjusted decline in the cost of cereals (Bouis 2000). This had a poverty-reducing effect, allowing people to spend more on other types of food. However, much of this additional purchasing power and impact on vitamin A status was presumably lost by the fact that over the same period of time the cost of lentils, vegetables and animal-source foods increased by 25-50% and the cost of fish probably doubled. Indeed, the real price for vegetables increased in several Asian countries during the 1990s and this was thought to be one major reason for low and stagnating levels of consumption (Ali and Tsou 1997). In such situations, efforts to increase production of foods important for vitamin A status are likely to be the most important measure, as this will cause their cost to fall. However, especially in the case of young children, nutrition education is at least equally important. In particular, failure to breastfeed optimally can result in severe VAD even in countries where diets are generally adequate (Wasantwisut et al. 2000).

Now let us address, one by one, the major constraints to the use and effectiveness of the most commonly implemented food-based approaches to combat VAD, similar to the process Solomons and Bulux (Solomons and Bulux 1997) used in developing processed high-carotene foods. Some of the broader cultural and other issues are described in (Kuhnlein and Pelto 1997).

1. *The greater cost of the best sources of vitamin A and of food-based approaches*

As mentioned above, increasing the local production and thus availability of vitamin A rich foods is probably the best way to reduce costs. This is particularly effective for foods that are too perishable to be marketed distant from where they are grown, given locally available technology.

In theory, increasing production of animal-source foods should bring down costs, increase availability, and increase vitamin A intakes. However, experienced to date is at best mixed (Leroy and Frongillo 2007). Liver is such a concentrated source of vitamin A that, as long as it is available, the provision of small amounts routinely to vulnerable groups could be a useful approach given that it is already the major source of vitamin A in some diets, even for toddlers ((Krause, Delisle and Solomons 1998)).

"Donor-centric" cost analyses often suggest that the universal vitamin A capsule approach is much more cost effective than food-based approaches. While the capsules do not cost much, current costs for distributing them are about 20 times higher than this (Neidecker-Gonzales, Nestel and Bouis 2007). However, these programs fail to reach anywhere from 5% to 40% of young children. The ones not reached would be much more expensive to reach per capita even though they would be likely to have a greater proportion with VAD.

In contrast, food-based approaches have been successfully targeted to virtually everyone, at least in rural areas (Greiner and Mitra 1995), and can provide economic benefits to a wide range of people including local farmers, transporters, traders, and purveyors of food. To reach the poorest groups, gardening initiatives need to be based on low-cost, low-risk technology and adapted to the types of environments to which low-income groups tend to have been marginalized (e.g. dryland gardens, flooding gardens). Even landless households can benefit from simple hydroponics, container gardening, the promotion of creepers that can grow on roofs, trellises and in trees, and from community or school gardening. New, vitamin A rich food sources may cost little to disseminate once they have been demonstrated and made available, as was seen in Mozambique where orange sweet potato's popularity spread on its own (Aguayo et al. 2005).

The costs of food-based approaches should be calculated over the much longer periods of time required for such programs to achieve optimal effectiveness. Unlike supplementation, they continue to function at least partially even once external funding has been withdrawn (Hussain and Kvåle 1996),(Kidala et al. 2000), (Faber et al. 2011). From the perspective of the host nation and particularly to communities that benefit from them, the net costs of food-based approaches may often actually be small or even negative.

2. Lack of availability of any low-cost sources during parts of the year, especially dry seasons

To counteract seasonal VAD, it is important to promote varieties that can be harvested at other times of the year or year-round. Relatively small plots can be affordably irrigated, particularly in or adjacent to the home and yet they can yield relatively large quantities (Ali and Tsou 2000), (Chadha et al. 2011). Small, scattered home gardens were found to be the ones most effective for increasing vitamin A intakes in Bangladesh (Bloem et al. 1996).

Keyhole gardens and other intensive agriculture approaches can enable low-income households to grow several types of vegetables year-round (Aphane, Pilime and Saronga 2011).

Another approach is to find low-cost ways of preserving high-carotenoid foods that preserve their provitamin A effect. Drying is perhaps the most important processing method available in low-income settings for increasing the off-season availability of high-carotenoid plant foods (Mensah and Tomkins 2003). Protected solar drying (that is, using the sun to generate heat to speed up the drying process but not allowing sunlight directly on the food) or oven drying leads to better carotenoid retention and less isomerization (cis forms are less well absorbed (Clydesdale et al. 1991)) especially when steam blanched in advance, than slow drying, especially in direct sunlight. Drying directly in the sun may completely destroy vitamin A, as in one fish variety tested in Bangladesh (Roos et al. 2002). An exception is cassava leaves, which do slightly better with direct sun drying.

Sweet potato flakes, suitable for making instant mash potatoes, can provide 7-9.6 RE/g, or 67% of the RDA per serving (Valdez C et al. 2001). Their vitamin A activity falls to about half after three months of storage in plastic.

In Thailand, candying of mango and papaya resulted in an 18% loss of beta-carotene + another 30-40% loss after 3 months storage (Chavasit et al. 2002). Pickling of vegetables actually increased beta carotene by 30%.

Simple processing methods can highly concentrate these foods so that a small amount delivers a sizable dose of carotene. The best known example is leaf concentrate, though it was originally promoted as a protein source. It has been shown to be effective in treating mild anemia (Vyas et al. 2010) and was found to reduce VAD based on conjunctival impression cytology (Khanna 2004) and SR (Davys et al. 2011).

3. Low consumption of good sources among vulnerable groups

Locally available and affordable sources of vitamin A may not be eaten in adequate quantities by young children and even sometimes by pregnant or lactating women. Indeed, for infants and young children, factors related to their care and health are likely to be more important than those related to household access to foods (Blaney, Beaudry and Latham 2009). Thus for this group, nutrition education is probably required (Ruel 2001) and may alone be able to have an impact (Yusuf and Islam 1994).

Experience suggests that vulnerable groups can and will increase consumption of vitamin A rich foods in response to well-designed behavior change campaigns (Food and Agriculture Organization of the United Nations and International Life Sciences Institute 1997). Ideally, such efforts should be coordinated with equally large-scale efforts to increase production of the relevant foods to avoid imbalances in supply and demand that can depress either consumer or local farmer interest in these foods (Greiner and Mitra 1995). Agricultural interventions with no behavior change component often fail to improve nutritional status, especially when focused on products over which men exert control or which can be easily sold (Bouis 2000).

4. *Locally varying constraints to increased levels of home gardening*

A multitude of factors must be taken into account in planning food-based interventions like home gardening. Kuhnlein outlines some easily overlooked cultural issues (Kuhnlein 2000). In Micronesia, an ethnographic approach was felt to be necessary to take cultural differences into account (Englberger, Marks and Fitzgerald 2004). Local concepts of food and its classifications there differed substantially from those in the West, yet there are few local nutrition specialists.

Most experts agree that home gardening is likely to be the most effective food-based approach in most low-income settings. Many gardening projects fail even at process level (and in such cases there is little point in evaluating them for impact (Greiner 1997)). Lack of community involvement and of nutrition education have greatly reduced the impact of efforts to combat micronutrient malnutrition in India (Vijayaraghavan 2002). Brownrigg (Brownrigg 1985) found the main cause of this to be “a lack of understanding of and adaptation to local conditions, resulting in extension agents, demonstration gardens, planting materials and garden establishment and management strategies unsuited for local environmental, social and resource supply conditions.” To be successful, such projects demand “that people have access to certain productive resources; that they not be denied access to a piece of land, or water, or advice from government extension agents, or be forbidden to trellis beans from the balcony of their housing project homes.” Producers who newly enter the market may need help accessing local markets. However, if maintained for a long enough period to overcome initial constraints, home gardening programs can achieve widespread implementation in low-income rural communities (Murthy, Lakshmi and Bamji 1999).

Clearly a major constraint in some locations is landlessness. In such areas, behavior change approaches targeted to their needs can be especially important. Some projects have dealt with this by focusing on providing support and inputs for the development of gardens on community or communal lands. One project in Bangladesh (Greiner and Mitra 1995) began by “renting” land for landless women’s groups—they paid the landowner by providing him/her with 50% of the harvest. But once the land was improved by fencing, mulching, composting, etc., the landowners usually took the land back, so this approach was abandoned. Instead, free seed was given to landless households for vine crops that provided high-carotene leaves and vegetables. These were then widely grown on roofs, trellises and even in nearby trees.

Large-scale community gardening programs in Zimbabwe and home gardening in Bangladesh have identified difficulties in obtaining (Zimbabwe) and maintaining (Bangladesh) fencing as the single greatest constraint. In both cases capital investment costs were too high. In Zimbabwe, metal fencing was required to keep out animal pests and communities’ inability to afford this was overcome through a national program. Communities competed for central funding for fencing (or other resources) for large community gardens. Those who designing programs in a way that was likely to achieve a wider range of objectives, including the reduction of malnutrition in local communities, were prioritized (Tagwireyi and Greiner 1994). In Bangladesh low income individuals utilized bamboo fencing to reduce damage from smaller animals like chickens and to warn pedestrians where not to walk. These require a small capital outlay for most and a good deal of time to construct. The former appeared to be the larger constraint (Greiner and Mannan 1999). The solution found was to utilize an agronomics expert to identify in each ecological niche which wild plants could best be utilized as (free) live gardens (Andersson 1994).

Some studies have suggested that the availability of improved seed may be the greatest constraint (Faber and van Jaarsveld 2007). This is likely a greater problem in countries which do not have well-developed local seed production facilities, requiring its import (Balcha 2001).

Access to water, less of a problem in kitchen or household gardens (which can make use of waste water, rain water collection, etc) can be a limiting factor for larger gardens. In Zimbabwe central government support was provided only to community gardens that could prove that the land allocated to the project was adequately close to a water source. In some cases, the water sector, part of the intersectoral committees that oversaw the project, linked the development of new water sources to these community gardening projects (Tagwireyi and Greiner 1994).

In preparation for developing large-scale food-based programs, governments and donors may need to begin with pilot projects. The goal of these should be to learn lessons about efficient implementation and effectiveness, costs, and management and training needs. These can best be learned when such projects achieve at least subdistrict scale. Otherwise costs are likely to be overestimated and management needs underestimated (Greiner, 2013 (FAO book, in press)).

Targeting can be another challenge. Priority should go to areas most in need and in general, dry areas are more likely to suffer from VAD. Yet the special challenges in implementing food-based approaches under such conditions can actually inhibit implementation there if decision-making is based on narrow, short-term cost effectiveness criteria. In Zimbabwe, the national community gardening program was for years forced to allocate nearly equal resources to each province for political reasons. Only gradually was there acceptance that the level of need should be the major determining factor in resource allocation (Tagwireyi and Greiner 1994).

5. *Poor bioavailability of some of the low-cost sources*

There are many factors which influence the absorption and bioconversion of the various provitamin A carotenoids into retinol, too complex to be able to estimate this very accurately. Carotenoid levels in plant foods are influenced by many factors (species, variety/cultivar, color intensity, ripeness, storage) but not as much by others (geographic location, season, temperature, solar radiation, or cultivation practices) (Ali and Tsou 2000), (Maiani et al. 2009). However, because it affects the diet of dairy cows, season has a substantial impact on the carotenoid levels in milk.

The factor of greatest importance is the vitamin A status of the person consuming the food (Ribaya-Mercado et al. 2000). In one carrot supplementation trial, there was no response of SR and very little of serum beta carotene, but a very large response of SR among two children who were deficient at baseline (Bulux et al. 1994). Yet much research estimating the conversion rate has been done on vitamin A replete individuals or those with mild VAD. Only in individuals with severe VAD would conversion reach the highest possible levels (Thurnham 2007), but in such individuals factors inhibiting absorption, including persistent diarrhea, helminth infection, high fiber diets, and low levels of fat in the diet, are also then more likely to be present. Various forms of malnutrition can inhibit absorption of carotenoids (Maiani et al. 2009).

Carotenes dissolved in fat have the highest level of absorption. In many of the cheaper vegetables (including DGLVs and carrots), carotenoids are trapped within cell structures or complexed with proteins and are thus challenging for the body to absorb (Castenmiller and West 1998). When fed with radishes, beta carotene beadlets achieved only 65% of the level achieved in healthy men from beadlets alone (Huang et al. 2000). The level of absorption achieved from foods cooked in fat was 37% for sweet potatoes, 33% for carrots, and 27% for DGLV.

Improving the absorption of carotenoids

(Rodriguez Amaya 1997) warns about methodological problems in studying the impact of home food preparation on the carotenoid contents in foods. Focusing on retention rather than bioavailability, she recommends as little chopping and heating as possible; every food preparation method results in loss of vitamin A, varying from 5-43% (Sungpuag et al. 1999). When red palm oil is used in cooking, about 30% of its provitamin A effect is lost (Narasinga Rao 2001). Peeling of certain fruits and vegetables can also reduce carotenoid levels. Extreme heating such as deep fat frying and heat treatment in the industrial processing of red palm oil, can cause substantial carotenoid losses.

However, the most important provitamin A carotenoids are heat stable at most cooking temperatures (60-100 degrees C) (Khachik et al. 1992). Very little of the carotenoids leach into cooking fat and only a small proportion change to the less bioavailable cis forms during frying (Kidmose et al. 2006). Chopping, especially into very small pieces, and then cooking increases bioavailability (Castenmiller and West 1998) from 18% to 6-fold (van het Hof et al. 2000). Simply mincing spinach increases the bioavailability of beta-carotene, and liquefaction increases it even more (Castenmiller et al. 1999). Cooked and pureed carrots increased plasma beta-carotene levels three times more than consumption of an equal amount of raw carrots (Rock et al. 1998). For sweet potatoes, most cooking and drying methods appear to result in a 10-22% loss in all trans beta-carotene (Bengtsson et al. 2008), with boiling resulting in higher true retention of all trans beta carotene than roasting (Kidmose et al. 2007). Frying, while increasing losses, more than compensates for this by increasing bioavailability (Gomes et al. 2013). No loss of beta-carotene was observed in grated orange sweet potatoes allowed to stand for 4 hours (van Jaarsveld et al. 2006).

Small amounts of simultaneously consumed fat can greatly enhance the absorption of carotenoids. For example, stir frying carrots yields 6.5 times as much retinol equivalent as eating them raw (Ghavami, Coward and Bluck 2012). Some evidence suggests that only 3-5g of fat consumed at the same meal is adequate to achieve optimal beta-carotene absorption (Hof et al. 2000) and this can be in the form of other foods such as avocado (Maiani et al. 2009).

In a 9-week trial (3 meals/d) of a high-carotene diet in dewormed schoolchildren in the Philippines (20% of whom had low SR at baseline and 11% at endline), there was no difference in impact on serum beta-carotene or retinol status among those receiving 7, 15, or 29g fat per day (Ribaya-Mercado et al. 2007). Small amounts of red palm oil, especially the "Carotino" type that is refined so as to have no effect on taste, could be used as a food to food fortification by replacing (Benad and S. 2001) or blending it with other oils (7-10% by weight) (Narasinga Rao 2001).

Intestinal worms may flatten intestinal villi (Martin et al. 1984) and thus decrease the amount of carotene that can be absorbed. The large carotene crystals in carrots for example are soluble in the gut but this probably requires a long transit time (Castenmiller and West 1998). This can have a large impact at population level, for example leading to speculation that helminth infection may be the reason that a substantial proportion of the Indonesian women with young children who had an adequate intake of plant-based provitamin remained with low serum retinol levels (de Pee et al. 1999). Deworming may greatly increase carotene absorption (Jalal et al. 1998b).

Methodological challenges in measuring the impact of food-based approaches

A major challenge is that there is no standardized food-based approach. Some programs may simply promote home gardening, perhaps including a demonstration garden (Faber et al. 2001); others may provide increased access to seed or seedlings at an affordable cost (Kidala et al. 2000); and some may provide training, free seed at least to certain vulnerable groups, and other support (Greiner and Mitra

1995). They may or may not include a wide range of behavior change approaches to promote increased consumption of vitamin A rich foods, including training in preparation of new varieties and offering tastes, particularly to young children who may not be familiar with them (Faber et al. 2001).

Ionnatti et al (Ionnatti, Cunningham and rUel 2009) point out that rigorous controlled trials at the same level of quality as have been done for supplements are extremely expensive and simply have not been done on food based approaches. Thus, although it is known that food-based approaches can improve incomes, food production, availability, diversity and nutrient intakes, it is not possible to conclusively state what their impact is on nutritional status or to compare the cost-effectiveness of the different approaches.

By definition, food-based approaches take time to implement. When should baseline data be collected and when has implementation achieved an adequate level to justify doing an outcome evaluation? For long-term programs it may make sense to delay doing a baseline survey to reduce the historical threat to validity, that is, the risk that some unpredictable event external to the project greatly affects its impact. Changes in food prices for example may complicate interpretation of the findings (see for example (Greiner and Mitra 1995)). Events in the community may even threaten continuation of the study. For example, during one food-based study conducted among schoolchildren in Bangladesh, a radio report about foreigners exporting human tissue resulted in many parents refusing to allow endline blood draws despite reassurances from local school personnel (Persson et al. 2001a). It may also be wise to ensure via process evaluation that impact is possible/plausible before making the substantial investment usually involved (Greiner 1997). It is ideal but complex to implement an evaluation at exact yearly intervals to control for seasonal differences. It would be risky to conduct a dietary impact study for vitamin A status over a short period of time because individual intakes vary so much from day to day (Beard et al. 2007). To assess the true individual average intake with ±20% precision, 6 replicates of a 24-hour recall are required (Persson et al. 2001b).

Another major threat to the validity of evaluations of large-scale food-based programs is lack of comparability of experimental and control or comparison areas. Food based interventions can rarely be randomized at the level of the individual as can be done for supplement trials. In theory some of them (those that do not employ national mass media for nutrition education for example) could randomize communities, but food-based projects rarely get funding adequate to do evaluation on such a large scale. Donors interested in funding large-scale programs are often not interested in more scientific and thus expensive evaluations. Even were feasible, randomizing communities greatly increases implementation complexity. Having communities that receive no intervention risks causing community resentment and does not allow for any control of the Hawthorne Effect (changes in behavior resulting from knowing one is being studied). These problems can best be addressed by providing some useful intervention irrelevant to vitamin A status, but this would greatly increase costs.

Investigators must decide whether to add fat to the diet and/or deworm participants, either measuring the impact of these measures or implementing them with the control group as well. In some trials these measures alone resulted in such substantive increases in vitamin A status as to nearly drown out the apparent impact of the high carotene food being tested (van Jaarsveld et al. 2005).

The impact of food-based projects or programs

Ionnatti et al (Ionnatti et al. 2009) point out that despite the methodological weakness, evaluations such as theirs provide consistent and plausible evidence of impact on many factors such as consumption that are likely to have led to improvements in nutritional status over time. The first reviews of such studies published after the 1992 ICN (Gillespie and Mason 1994) included 16 diet modification programs, mostly pilot projects or field trials, two public health programs, and two breastfeeding programs, providing comparative data on program costs. Ruel (Ruel 2001) covered the period 1995-2000. Some recent general reviews of the impact of agricultural projects on nutrition have included some reference to vitamin A such as (Berti et al. 2004), (Masset et al. 2011), (Arimond et al. 2011), and (Girard et al. 2012).

Table 2 summarizes outcome data on consumption, vitamin A status, and others from evaluations of food-based interventions that have been reported since the 1992 ICN. Only in the Philippines (Solon et al. 1996) and Indonesia (Reis et al. 1996) were these interventions conducted by governments, though many others were on a very large scale.

Table 2. Impact on vitamin A of food-based interventions (studies published after 1992)

Reference	Location	Target Group	N	Intervention and duration	Impact on consumption	Impact on vitamin A status in $\frac{\mu}{\mathrm{mol}}/\mathrm{L}$	Other impacts
(Low et al. 2007)	Mozambique	Drought-prone province with ~10% VAC coverage	827 HH	2 exp districts and 1 control; 2 yr; promoting production and consumption of OFSP[a]	Net[b] 32% increase in children consuming during secondary harvest; 370RAE[c]/d greater retinol intake post intervention	Net mean change in SR[d] 0.076, p<.01; Net 22% reduction in children with low SR to 38% at endline	Net 74% increase in families producing, 50kg increase in production and 22% increase in sale
(Kumar and Quisumbing 2010)	Bangladesh	Saturia subdistrict	409 HH[e]	Introduction of 9 new vegetable varieties for small scale home production 2yr before survey	Increased vitamin A by men and women but not children		
ditto	ditto	Jessore subdistrict	448 HH	Leasing of ponds to women's groups 3 yr before survey	No impact		
ditto	ditto	3 subdistricts in	380 HH	Training and credit to HH already owning ponds 6yr before	Increased vitamin A by men and women,		

		Mymensingh		survey	not children		
(Faber et al. 2001); (Faber et al. 2002)	South Africa	9 community health centers in one rural area	50+50	1 yr, Demonstration garden, promotion of gardening and consumption; cooking demonstrations and taste testing	Increased consumption of 4 types of vegetables and 6 types of fruit; Net increase of ~699 RE/d in children 2-5 yr	Net change in SR 0.15	
(Olney et al. 2009)	Cambodia	1400 HH in one province	300 HH +200 Control	5 yr program; 19-mo between surveys; HKI homestead food production program: training, nutrition education, seed	Increased HH F&V consumption ; increased egg consumption by children<5; increased MN rich food by women		Net increase in HH F&V production of 62 kg/mo; lower prevalence of fever among children<5
(Smitasiri et al. 1999); (Smitasiri 2000)	Thailand	4 subdistricts in NE	42 girls 10-13 yr	Several interventions but mainly village gardens + nutrition education; 1 yr	Increases in vegetable and vitamin A intake in women and children	Net increase in SR 0.77	Improvements in knowledge and attitudes compared to control area (4 similar subdistricts)
(Hagenimana et al. 2001)	Kenya	5 women's groups	154 children 0-5	Nutrition education (both intervention and control received sweet potato), 1 yr, 7 mo	Frequency of consumption of vitamin A rich foods, net increase 2.9 times/wk		Consumption of both animal and plant sources increased

(Chakravarty 2000)	India	30 villages in 3 blocks in West Bengal	1500 HH	Establishment of nurseries to provide seed; improved access to water; gardening equipment; horticultural and nutrition education	DGLV increased by 15g/d (no control group); high carotene fruits by 7.5g/d	Xerosis decreased from 6.4 to 3.5%; Bitot's spots from 2.8 to 0.8%; and nightblindness from 15.3 to 4.7%	Knowledge increased about the importance of vitamin A and which foods contain it
(Vijayaraghavan et al. 1997)	India	20 villages in South India	200 HH	Distribution of seeds and seedlings and nutrition education to HH w preschool children, 3 yr	50% consuming carotene-rich foods compared to none at baseline (no control);	12% of preschoolers participating for 1 yr had Bitot's spots compared to 6% participating for 3 yr (NS[g])	HH growing carotene-rich foods increased from 10% to 65%; increase in knowledge of cause of nightblindness increased from 0-29%
(Worldview International Foundation 1995)	Bangladesh	Rangpur District	?	Comprehensive program promoting home gardens and using a wide variety of media for nutrition education, 3 yr		XN[h] declined from 5.4 to 3.2% from 1987 to 1990 (no control)	Nearly 1 million home gardens were developed
(De Pee et al. 1998b)	Indonesia	Women and young	~5000	Social marketing of eggs and DGLV over	Eggs in past week among women		Vitamin A intake increased

		children		1 yr	increased from 80-92%; young children 78-92%; vegetables prepared from 93-111g/person/d		from 335-371 RE/d for mothers and 130-160 RE/d for children
(Nana et al. 2006)	Burkina Faso	Children 2-3 yr	69	15 wk, home visits promoting consumption of liver and mango; no control group	Increase from 12-155 RAE/d from liver but decrease in mango consumption		Overall intake of vitamin A increased from 68% to 102% of safe intake level
(Mulokozi et al. 2001)	Tanzania	Children 1-6	36	Subsidized vegetable dryers, nutrition education	Net increase in consumption of high vitamin A foods of about 2 times per week		
(Laurie and Faber 2008)	South Africa	7 villages in Eastern Cape	219 HH (controls: 223 non-participating neighbors	3 yr, nutrition education, demonstration gardens in each village, training of agric extension agents	Increased frequency of consumption by children of 4 of 6 high-carotene foods; NS for other 2		Lower self-reported morbidity in 2 weeks prior to survey (statistically significant differences in 6 of 7 symptoms); more HH cultivated vegetables

(Gibson et al. 2003)	Malawi	Stunted children 2-7 y/o in 2 villages	200	Nutrition education	No difference in vitamin A consumption at endline		
(Hotz et al. 2012)	Uganda	Children 3-5 y/o in 3 districts w .10,00 HH	>1000 intervention+ control	2 yr; distribution of 20 free OSP vines/HH; agric, nutr and marketing education; establishment of district marketing stalls; less intense in yr 2 (RP)	Net increase in OSP intake, net increase in vitamin A in all non-breastfed groups, no difference with IP; net decrease in those w inadequate vitamin A intake except children 3-5		
(Hotz et al. 2012)	Uganda	Children 6-35 mo; 3-5 y/o and women in 3 districts w .10,00 HH	>1000 intervention+ control	2 yr; distribution of 20 free OSP vines/HH; agric, nutr and marketing education; establishment of district marketing stalls; equally intense in yr 2 (IP)	Net increase in OSP intake; net increase in vitamin A in all non-breastfed groups; no difference with RP; net decrease in those w inadequate vitamin A intake except children 3-5	Net infection adjusted in dewormed children 3-5 yr: 0.04; not dewormed: 0.002; in both cases, among children with baseline <1.05	
(Delisle et al. 2001)	Kaya District, Burkina Faso	Women and children <5 yr	10,000 for inter	Social marketing of red palm oil, 1 yr	Mothers increased from ~140-570 and children from ~60-3500 µg RE/day		

			venti on; ~400 for study				
(Zagré et al. 2003)	Kaya District, Burkina Faso	Women and children <5 yr	10,0 00 for inter venti on; 210 for study	Social marketing of red palm oil, 2 yr	Mothers increased from ~235-655 and children from ~164-514 µg RE/day	Rates of serum retinol ,<0.70 mmol/l decreased from 61.8 - 8.0% to 28.2 - 11.0% in mothers, and from 84.5 - 6.4% to 66.9 - 11.2% in children	
(Ayalew, Gebriel and Kassa 1999)	3 districts in Ethiopia	Young children	Inter venti on: 500 famil ies; 214 samp led	Provision of a dairy goat on credit (earlier shown NOT to have an impact on nutrition), veg seed and nutrition education; 9mo intervention period; impact measured 6 mo later	22% increase in children consuming milk >4 times/wk		Post intervention, 4% of right and 4% of left eyes had Bitot spots in non-participant young children (n=165) compared to 0.01 and 1% respectively in participating

							children (n=509)
(Greiner and Mitra 1995)	All rural people in entire district of Gaibandah, Bangladesh	Young children	~2500	Complex integrated set of behavior change, school, and household gardening interventions; evaluation measured impact of only the third year of a 3-yr project	Net increase of 22.2% o households consuming green vegetables; 18.9% net increase among young children; yellow fruit consumption increased by 11 and 12% but change in control group was equally large		No significant impact on prevalence of nightblindness
(Kidala et al. 2000)	Singida Region, Tanzania	Families	125 HH	Horticulture and nutrition education done in five villages; provision of solar driers; evaluation was done 5 yr after completion of a two-year intervention	65% in exp area consumed vitamin A rich foods in past wk compared to 36% in control area	In post-intervention sampling, higher in control area (19.4 vs 14.0mcg/dl) but higher w greater veg consumption (r=0.21) and in those w no helminths 24.0 vs 12.3 mcg/dl	Had a home garden: 67% interv vs 31% control; has and still uses solar drier: 43% (of 44% who received them) vs 0%; grows carotene-rice crops provided 5 yr before: 67% vs 28%
(Parlato	Tahoua		Inter	3 yr, social market	Consumption of liver		

1996)	Province, Niger		venti on 250, 000	campaign promoting increased consumption of liver as a snack food, wild DGLV, yellow squash and mango by women and children and increased dry season production of DGLV	in previous week by women increased from 43-73%; for children from 37-49%; for DGLV, children, from 57-94%; feeding DGLV at 6 mo of age increased from 52-59%		
(Yusuf and Islam 1994)	3 villages in Bhola District, Bangladesh	Children <6 yr	1065	Nutrition education via HKI materials and group presentations encouraging home gardening for 18 mo	Vegetable consumption increased from 15.1g/d to 46.4g/d; oil from 4.5g/d to 12.0g/d		Number of nightblind children decreased from 68 (4.1%) to 5 (0.47%) (no control)
(Rahman et al. 1994)	Former ICDDR,B patients, Dhaka	Children 6-35 mo	44	Single session of nutrition education and single feeding demonstration	8 weeks later, 57% fed DGLV on day of home visit compared to 26% controls (neighbors)		
(Rahman et al. 1994)	Former ICDDR,B patients, Dhaka	Children 6-35 mo	36	Single session of nutrition education only	8 weeks later, 64% fed DGLV on day of home visit compared to 26% controls (neighbors)		
(Solon et al. 1996)	Cagayan de Oro	Young children, pregnant and	Int: 400, 000;	Promotion of production and consumption of 5	Household consumption of 3 of the 5 increased >25%,		

	Philippines	lactating women	survey 300	provitamin A rich vegetables via mass media (3 mo) and community and school outreach (5 mo)	small for the other two; control area <10% increase for 2 and no change for other 3; among children <6yr, carotenoid intake increased 12% compared to 48% decrease in control area		
(Phillips et al. 1996)	2 departments in Guatemala	Women of childbearing age and children <6	1.2 million pop	HOPE project promoting increased production (providing seed for home gardens) and consumption of high provitamin A foods, evaluated after 3 yr	85% adopted home gardens; those without gardens were 3.5 times more likely to have children with VAD controlling for several confounders		
(CARE Nepal 1995)[i]	Nepal	Children 6-60 mo		Homestead gardening, irrigation, agriculture extension, seeds	Insufficient VA intake for mothers and children both pre- and post-intervention		Increase in % of HHs producing vegetables
(English and Badcock 1998)	Vietnam	Mothers, children <5	5600 HH, 2 yr	Promoting HH gardening (VAC system); nutrition	Doubled children's vitamin A intake (100 RE) compared to		

				education	control area (50 RE)		
(Aphane et al. 2011)	Lesotho	Families with HIV-infected members	62 villages	Promoting and assisting families to build and cultivate keyhole gardens (in addition to other interventions)	Increased community production of vegetables from 10% - >20% of their needs.		
(Ahmed, Jabbar and Ehui 2000)	Ethiopia	Low-income HH	60 for surveys	Introduction of crossbred cow and improved feeding and management technologies, 2 yr between surveys	At endline, intervention families consumed 38.8 RE and control 27.1 RE		
(Rajasekaran Unknown, after 1993)	India	Low-income HH	Not specified	No intervention. HH engaged in a production system with ducks and fish were compared with nearby HH that were not	At endline, intake of vitamin A in participating HH was 2486 IU and controls 1586		

a. OFSP = “orange-fleshed sweet potato

b. When papers did not calculate a difference between changes that took place in the intervention and control groups, the mean of the change in control group values was subtracted from the mean of the change in the intervention group and this is referred to as the “net” value. Values presented represent increases unless preceded by a – sign.

c. RAE=retinol activity equivalent

d. SR = “serum retinol”

e. HH = “households”

f. F&V=”fruits and vegetables”

g. NS = “not significant”

h. XN=”nightblindness”

i. Based on data in (Berti et al. 2004)

Not all program evaluations reported data in ways that could be included in Table 2. Helen Keller International has implemented integrated Household Food Production Programs among 30,000 households in Bangladesh, Cambodia, Nepal and the Philippines and found that they result in increased consumption of vegetables and fruits as well as eggs and liver (Helen Keller International--Asia-Pacific 2010). Masset et al. (Masset et al. 2012) conducted a meta-analysis of four intervention studies and found an average impact of 0.24 μg/L in serum retinol between project and control areas (z test of significance 6.35; P<0.001). They conclude that there is evidence that home gardens improve vitamin A intake among children less than 5 years of age. The Good Start in Life Program in Peru is a comprehensive health program including vitamin A supplementation, promotion of increased consumption of high carotene foods, of exclusive breastfeeding and of improved complementary feeding. Covering an area with a population of about 1 million, it reduced VAD (SR<20μg/L) from 30.4% to 5.3% in children less than three year old in four years of implementation (Lechtig et al. 2009).

Ruel found that only when home gardening programs were combined with nutrition education did they have a measurable impact on vitamin A status (Ruel 2001). Combining various approaches, avoiding duplication of efforts, developing synergy, and involving multiple sectors are among the challenges that need to be faced (Finley and Darnton-Hill 2001). Intersectoral approaches have long been advocated in nutrition but have the reputation of fostering more bureaucracy than efficiency. Perhaps the major ingredient needed to transform the efficiency of intersectoral work is that each member of the intersectoral group has the possibility to obtain a share of available funding or have some impact on the use of an existing budget (Tagwireyi and Greiner 1994).

Assessment, monitoring and evaluation

Since mortality is so extremely difficult to use as a monitoring and evaluation (M&E) outcome (requiring unfeasibly large sample sizes and in many cases preventing the use of control groups for ethical reasons), serum retinol, thought to be the best biochemical indicators of vitamin A status, should be used universally for program M&E (Semba et al. 2010a). However, immunoassays based on retinol binding protein (RBP) can in many cases be used instead of serum retinol for this purpose, at a much lower cost. It is simpler and more feasible to use under conditions in which access to high quality laboratories is limited (Baingana, Matovu and Garrett 2008).

However, only once liver stores are exhausted is either SR or RBP a useful indicator. In less severely deficient populations, the modified dose response test, though relatively expensive, may often be the best method of assessment (Tanumihardjo 2011). In research intending to measure the impact of a food-based intervention, serum beta-carotene should also be used because of its more rapid responsiveness (De Pee 1996).

Policy alternatives

Supplementation programs reach 5-10% of the population. Yet there is some evidence that pregnant and lactating women ought to be considered of equal importance as a vulnerable group as young children (West et al. 1999) and it is now recommended that asking women about night blindness during a recent past pregnancy be used in assessing whether VAD is a public health problem (Semba et al. 2010a). Donors and governments must be proactive in implementing food-based approaches that will sustainably provide adequate diets not only to these groups but also to the rest of the community.

The universal distribution of VAC can be phased out by first shifting to disease-based VAC distribution. VAC can be provided to all health facilities to be given to all young children presenting with a locally determined list of relevant diseases or malnutrition. Ensuring that zinc and oral rehydration treatment of dehydration from diarrhea is available at all health centers and dispensaries, and that measles vaccination is functioning so well that measles is either eradicated or a rare occurrence will also greatly reduce the known basis by which megadose supplementation could have an impact on mortality.

Mandatory food fortification programs can also assist in the process of phasing out universal supplementation programs, but should be monitored through a simplified dietary assessment and sampling of biochemical indicators. Another approach to this phasing out process could involve implementation of intensive food-based approaches on a district by district basis (for example, the comprehensive model developed in Bangladesh (Greiner and Mannan 1999)), as funding and capacity building allow. Decision making on when to phase out universal supplementation (or shift to disease-based supplementation) could be done every few years as was done in Tanzania in phasing out iodized oil capsule distribution (Peterson et al. 1999) based on simplified dietary assessment techniques (Rosen, Hasselow and Sloan 1993), (Omidvar et al. 2002) and sample testing of biochemical indicators.

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