Combatting Vitamin A deficiency: overcoming obstacles to optimize the food-based approach

By Ted Greiner, PhD, Formerly Professor of Nutrition, Hanyang University, Seoul, South Korea

Abstract

Food-based approaches to combat vitamin A deficiency (VAD) continue to be largely ignored by governments and donor agencies. This review deals with common misperceptions as well as constraints that may lay behind this reality. First, high-dose vitamin A capsules provided to preschool age children are no solution for VAD. Second, researchers may assume that it is not possible to standardize foods adequately to study their efficacy in controlled trials. This review summarizes the results of 57 such trials, providing an overview that may assist researchers in making decisions on target groups to study, types of food supplements to provide, quantities, supplementation periods, impacts that are realistic to expect, and sample sizes. Even more complex is to design efficacy trials or impact evaluations of interventions. Again, the paper reviews 40 such trials, providing summary information on approaches, target groups, sample sizes, periods of intervention, and impacts measured using a variety of indicators. There are a number of barriers or constraints that must be planned for and overcome if food-based approaches are to work. This paper reviews several of the most important ones, briefly touching on many of the most effective ways that have been found to overcome them. Food-based approaches can reach all members of the community, are safe for pregnant women, tend to be at least partially sustainable, and confer a wide range of nutritional and other benefits in addition to improving vitamin A status. Food-based approaches are sometimes described as expensive, but this is based on a narrow view. For example, biofortification and dissemination of sweet potatoes cost $9 to $30 per disability-life-year (DALY) gained, while that from VAS was estimated at the estimated cost effectiveness of VAS is $73 per DALY gained. From the community point of view, the economic benefits of food based approaches are likely to subsidize or outweigh their costs.

Key words: vitamin A, carotene, carotenoids, food-based, efficacy, effectiveness, low-income countries, nutrition interventions, high-dose vitamin A capsules, retinol, red palm oil, biofortified, orange and yellow fruits, dark green leafy vegetables

Introduction

A few years ago, UNICEF estimated that 1 in 3 pre-school aged children and 1 in 6 pregnant women were vitamin A deficient (UNICEF 2013). Lactating women are often affected as well, in some cases at alarmingly high levels (Ncube, Malaba, et al. 2001). Food-based approaches to improve nutritional status have largely succeeded in eliminating most micronutrient deficiencies as public health problems in most industrialized and apparently some newly industrializing countries like Thailand (Wasantwisut, Chittchang, and Sinawat 2000). Yet these approaches continue largely to be ignored by development agencies and many governments, with the partial exception of food fortification and, in recent years, biofortification. This is partly because dietary sources of retinol are expensive and plant sources of carotene are assumed to be so poorly absorbed that they cannot meet dietary needs.

This review provides evidence that the widespread claims that these food-based approaches (except fortification) do not work are incorrect. All relevant studies that could be located dating back to 1992 are reviewed in tabular form for both clinical trials (studies of efficacy) and project evaluations (studies of effectiveness), indicating which ones do and do not show evidence that a certain food or group of foods at a certain dose to a certain group for a certain period of time improved vitamin A status (as measured by serum retinol). Some of the earlier research is reviewed by Soleri, et al. (Soleri, Cleveland, and Frankenberger 1991).

This review then discusses the commonly occurring constraints and barriers to the food-based approach and ways of overcoming them, and finally how the nutrition policy agenda can be changed to bring about a shift to the food-based approach in addressing VAD. Food fortification has been well reviewed in the existing literature, and is thus not included here. Biofortification, often is simply based on conventional plant breeding, is included however.

Methods

Literature searches were done using “vitamin A” “caroten*” and “food-based” as search terms. Only research in humans was included. All relevant papers found on Pubmed were included. In Google Scholar, all relevant additional papers were included from 214 pages of links, after which five pages of links contained no additional relevant papers and the review ended. Additional papers were located from relevant websites (IFPRI.org, FAO.org) and from downloaded papers’ reference lists. Full text papers from open access journals and journals subscribed to by Hanyang University, Seoul, South Korea were downloaded and included. This resulted in 361 papers eligible for inclusion. Review papers were scanned and when relevant data were found, the original research articles were referred to. Many research papers provided no additional relevant information and thus are not included in the reference list below. However, all papers including serum retinol data from either a clinical trial or a project evaluation were included in the two tables and reference list. It can be noted that while the search period covered 1992-2017, an increasing proportion of relevant research involved biofortification in recent years.

Benefits of the food-based approach

Nair et al. (Nair, Augustine, and Konapur 2015) provide a comprehensive review of the advantages and disadvantages 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 (diversity) to their diets can be achieved through promoting increased consumption of a range of nutritious foods, many of which will contribute to improving vitamin A status. Indeed, vitamin A deficiency disappears at a much lower level of income than is the case for other nutritional deficiencies (Barrett and Bevis 2015).

Producing high pro-vitamin A foods can result in increased income for local farmers and others working in the food chain. Economically, 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 in low-income countries the cost and/or lack of cold warehousing and transport means these foods must be grown locally where the malnutrition exists. This almost ensures that the income generated (or food substitution effect) will accrue to small farmers or households with home gardens. Some two-thirds of the people suffering from hunger are 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 imports from large Northern companies and/or external donor agencies.

Children with low vitamin A intakes tend to come from families with low socioeconomic status, who are also the ones least likely to receive high dose vitamin A capsules (HDVAC) (Semba et al. 2010). The increased income achieved via household gardening was found in one study 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.

It is common that in settings where one micronutrient is deficient, others are as well (Torheim et al. 2010). Individual nutrient supplements and multi-micronutrient powders do not contain as many nutrients and lack other health-promoting constituents like dietary fiber and polyphenols. Vegetables in particular provide an impressive range of nutrients (Grubben et al. 2014). In some cases, like lycopene, the whole food (tomato) appears to function better on most indicators than the nutrient when given as a supplement (Burton-Freeman and Sesso 2014).

Dietary improvement is now often the preferred intervention in industrialized countries (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). However, Girard et al. (Girard et al. 2012) in reviewing 32 papers based on 17 agricultural projects, consistently found improved diets and vitamin A intakes, but summary estimates did not show significant improvements in young child nutritional status. Effects on vitamin A status, anemia, and morbidity were inconsistent.

While economic constraints, donor preferences, and ecological constraints (such as iodine deficiency in soils) may sometimes limit their applicability, food-based approaches are generally the most sustainable approach to use in settings where multiple nutrients are deficient in diets of several groups in society. 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). Biofortification and dissemination of sweet potatoes cost $9 to $30 per disability-life-year (DALY) gained (Meenakshi et al. 2010), while that from VAS was estimated at the estimated cost effectiveness of VAS is $73 per DALY gained (Fiedler et al. 2014). Nair et al (Nair, Augustine, and Konapur 2015) address program affordability in detail.

Food sources of vitamin A

A wide range of foods containing either preformed vitamin A (retinol, present in animal foods) or pro-vitamin A (certain carotenoids found in plants that can be turned into retinol in the body) are widely available and acceptable to nearly everyone in all countries. The most commonly available sources of preformed vitamin A are milkfat, eggs, liver, and certain fish. Of all the commonly used varieties of seafood in Bangladesh for example, the viscera—which could be assumed to be the only or main source of retinol in fish--are consumed in only one species (Bogard et al. 2015). It was found that retinol content did not seem to depend on the presence of viscera, but it was high in only one species (*Mola*) and at moderate levels in 4 or 5 others; most had almost none. Because retinol is highly bioavailable, relatively small quantities of these animal-source foods can have a large impact on vitamin A status. Breast milk is the most important food source of retinol for infants and young children in low-income settings. WHO recommends exclusive breastfeeding for all infants, and does not warn that it is insufficient in vitamin A even when mothers' diets are deficient. Achieving optimal breastfeeding practices thus ought to be the first priority of food-based approaches.

The most commonly available foods that contain significant quantities of provitamin A, listed in order of the bioavailability of their carotenoids, are (1) oils that are orange or red in color such as red palm oil; (2) non-citrus fruits that are yellow, orange or red in color; (3) root crops, squash and pumpkin that are deep yellow or orange; and (4) most green vegetables, with very high levels but relatively low bioavailability in some dark green leafy vegetables (DGVL). The carotenoids in fruit are not only better absorbed than those in vegetables (de Pee, West, et al. 1998), they are also more easily accepted by many young children.

Graham and Rosser (Graham and Rosser 2000) maintain that certain varieties of existing staple foods that are exceptionally high in carotenoids (including wheat, maize, potato, sorghum, cassava and sweet potato), could probably eradicate VAD if widely planted and consumed. Where heavily consumed, highly colored banana and plantain varieties could also routinely provide large quantities of provitamin A (Fungo and Pillay 2011) (Englberger 2001). Most of these foods can be cultivated in most low-income countries 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, though of course they may be time-consuming to obtain. Unfortunately, they often also have such low status (perceived as poor people's food) that they are largely ignored. Biofortified foods have great potential, but are in the early stages of large-scale implementation (Tang 2013). Orange fleshed sweet potato, many varieties of which are the result of conventional breeding, are of particular interest because it gives a high yield with limited inputs and white varieties are already widespread. Of 15 varieties tested in Bangladesh, β-carotene content varied from 2890 mg/100g (IGSP-15) to 9740 mg/100g (ST-14) (Mitra 2012). Typically, about 80% of this was retained when the tubers were cooked.

The impact of foods on vitamin A status

Making the case that natural foods alone can normalize vitamin A status for low-income populations is complex for several reasons. First, in low-income populations there has been limited research. Second, past research 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 in real life. Food 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 (Solomons and Orozco 2003). Third, the methods used in most past research have been too weak to allow for decisive conclusions.

Table 1 summarizes findings from the trials of foods that have been conducted since 1992 and provide data on changes in serum retinol (SR). When available, serum beta carotene values are also listed. Such trials, when controlled and randomized, are often referred to as efficacy studies. When reports note whether or not deworming was done in advance or additions of fat were made to the diet, these are noted because of their substantial influence on carotenoid absorption. Very few studies calculated net changes, and thus the specific information included in the table was rarely tested for significance.

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

Reference	**Food**	**Quantity/day**	**No. of days**	**participants**	**N**	**Impact on serum $\boldsymbol{\beta-}$carotene in $\frac{\mu}{mol}/L$**	**Impact on Serum retinol in $\frac{\mu}{mol}/L$**
(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 *trichuris* 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)
(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 et al. 2001)	Red palm oil	6 doses, each containing 15 mg beta-carotene total	10 d	Lactating women (w children 1-24 mo)	32	Net 0.3 (infant 0.18 but placebo was the same so net 0)	Net 0.02 (infant net 0.06)
(de Pee et al. 1995)	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)
(de Pee, West, et al. 1998)	Orange fruits	2 meals/d providing 535 RE[h]	6d/wk for 9 wk	Anemic children 7-12 y/o, most helminth-infected	49	Net 0.49	Net 0.07
“	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

(de Pee et al. 1998c)	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
(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
"	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
(Egbi et al. 2017)	Red palm oil	300g/d in boiled cowpeas for lunch	3d/wk for 6 wk	Children 6-12 yr	142		4.05 µg/dl increase, no control; 17% decrease in VAD
(Gannon et al. 2014)	Biofortified maize	276g/d, 394.8 mg RAEs/d	90 d	Preschool children	135		Net -0.02 Body reserves net 97 mmol
(Haskell et al. 2004)	Spinach	60g/d of Pureed spinach providing 750 RE	60 d	men	14	Net 0.24	Net 0.34
"	Cooked pureed Indian spinach	75 g twice a day, total 4.5 mg beta-carotene	60d	Men	14	Net 0.27	Net 0.34
"	Sweet potatoes	60g/d of Pureed sweet potato providing 750 RE	60 d	men	14	Net 0.21	Net 0.23
"	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. 2005)	Goat liver	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	52	-.03 (no control)	~0.3 (no control)
"	Amaranth leaves	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	51	0.05 (no control)	No change (no control)
"	carrots	850 g retinol equivalents/d	6d/wk for 6 wk	Nightblind women	53	0.12 (no control)	~0.05 (no control)

(Jalal et al. 1998)	fat + deworming	15g fat/d + deworming 1 wk previously	21 d	Children 3-6 y/o	38		Net 0.15
"	Sweet potato and veg's	Enough to supply 750 RE/d	21d	Children 3-6 y/o	39		Net 0.2
(Jalal et al. 1998)	Deworming +food	Deworming 1 wk in advance plus 750 RE food/d	21d	Children 3-6 y/o	38		Net 0.25
"	Fat + food	15g fat+750 RE food/d	21d	Children 3-6 y/o	39		Net 0.35
"	Fat+deworming +food	15g fat, deworming and 750 RE/d food	21d	Children 3-6 y/o	40		Net 0.32
(Jamil et al. 2012)	Boiled orange sweet potato	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
"	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
(Kehoe et al. 2015)	DGLV+ dried fruit+ whole milk powder	25g fresh green leafy vegetables (e.g. spinach, *colocasia*, coriander and fenugreek leaves), 10g dried fruit (e.g. Figs, dates and raisins) and 12g whole milk powder fried in oil; total weight 65g	12 wk	Non-pregnant, non-lactating women 14-35 y/o	170	Net 35 (when other variables were controlled, 47)	Net 18 (when other variables were controlled, 1)
(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
"	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

“	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
(Kongsbak, Thilsted, and Wahed 2008)	Mole fish	50g fish curry providing 600 RAE	6d/wk for 9 wk	Children 3-7 yr	61	RBP[i] Net -0.02	Net -0.05
(Lartey et al. 1999)	Fish powder	20% fish powder added to porridge as complementary food	6 mo	Children 6-12 mo of age	53		-0.03 no control
(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; 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
(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)
“	Red palm oil snack	Contains the RDA, 2.4mg $\boldsymbol{\beta-\text{carotene}}$	Daily for 2 mo	Children 7-12 yr w VAD	18		0.90 (no negative control)
“	Red palm oil snack	4g red palm oil in a snack containing 50,000 IU vitamin A	Daily for 15 d	Children 7-9 yr	12		0.52 (no negative control)
“	Red palm oil snack	8g red palm oil in a snack containing 100,000 IU vitamin A	Daily for 15 d	Children 7-9 yr	12		1.19 (no negative control)
(Ncube, Greiner, et al. 2001)	Grated carrots	100g + 10g fat	60	Women breastfeeding babies 2-12 mo old	49		Net 0.3; Net reduction in VAD 15%[c]

"	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]
(Persson et al. 2001)	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
"	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
(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
(Ribaya-Mercado et al. 2000)	Orange fruits and vegetable s	1 meal and two snacks daily providing 12 mg beta carotene	5d/wk for 12 wk	Dewormed 7-13 y/o school children	27		0.38 (no control)
(Siekman n 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)
(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
"	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
(Takyi 1999)	DGLV + 20g fat	Provided 400 RE[g]	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

(Talsma et al. 2016)	Biofortified cassava	1460 µg β-carotene/d in 371g cassava	6d/wk, 18.5 wk	Children 5-13	382 (109 exp group)	Net 0.51	Net 0.01
(Tang et al. 1999)	Green-yellow vegetables	238g/d	5d/w for 10 w	Kindergarten children	22	Net 0.27	Net 0.23 ($p<0.02$)
(Torronen 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)	
"	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)	
(Turner et al. 2013)	OFSP	12 mg β-carotene/d in 100g OFSP	6d/wk, 3 wk	Lactating women 18-45 y/o	34	Net 0.28	Net 0.08
"	tangerines	5.3 mg β-cryptoxanthin/d in 127g canned tangerines	"	"	33	Net -0.01 (Net 0.55 β-cryptoxanthin)	Net 0.02
(van Jaarsveld et al. 2005)	*Resisto* (orange) sweet potato	125g providing 1031 RAE[f]/d, 2.5 times the RDA[g] (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
(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
(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

a. When papers did not calculate a difference between changes that took place in the intervention and control groups, the mean of the reported change in control group values was subtracted from the mean of the change in the intervention group and this is referred to in the table 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. OFSP=orange fleshed sweet potato

f. RAE=retinol activity equivalents

g. RDA=recommended daily allowance

h. RE=retinol equivalents

i. RBP=retinol binding protein

The “ sign is used in the table to mean “ditto”, that is, this box is identical to the box above it.

Table 1 reports the results of supplementation trials of 57 foods or food combinations from 34 publications. Most report on changes in SR in experimental vs control groups; in a few cases changes in serum β-carotene are also reported. Because the amounts of food and duration of the trials are reported, this may prove useful for planning other such studies. In particular, it provides an indication of what SR changes are realistic to expect with which types of research subjects and sample sizes.

Among the foods tested in the studies included in this table, there was a net positive impact on SR after subtracting the change in the control group in 42 of them and a net negative impact in 3 of them. Among the trials that had no negative control group, there was a positive impact in 7 and a negative impact in none. Among the trials that tested changes in breast milk retinol, 5 trials had a net positive impact and 1 trial had a negative impact. One trial had a positive impact on newborn cord SR. One trial with and another trial without controls recorded no change in SR. Two trials recorded net reductions in vitamin A deficiency of 13% and 15%.

Among the foods tested in trials that had control groups, there was a net positive impact on serum beta carotene after subtracting the change in the control group in 24 of them and a negative impact in none. Among the trials that had no negative control group, there was a positive impact in 5 and a negative impact in one. Among the trials that tested changes in breast milk retinol, 5 had a net positive impact and none negative. Two trials had no change. One trial registered a negative change in RBP.

As mentioned above, in hardly any of these trials did authors report net changes. The net changes reported in the table were calculated by subtracting control group changes from intervention group changes. This procedure did not allow significance testing to be done and in many cases the positive changes were small; negative changes were rare and small in all such cases.

Given that the impacts are overwhelmingly positive and took place over a relatively short period of time, it is clear that provision of adequate quantities of foods rich in retinol or provitamin A can prevent VAD, and, in the case of red palm oil, could be used to treat it (Mahapatra and Manorama 1997). Indeed, the recommended dietary intake of VA for all 208 million people most in danger of VAD worldwide for 1 yr is 0.80 million metric tons, a fraction of annual world palm oil production (Kopec et al. 2014).

Fewer studies are reported from Africa than from Asia and Latin America, although much of global VAD is located on that continent. More so than the other regions, food based approaches, certainly in the Sahel but in many other regions as well, are limited because of the dry climate and lack of surface water. Nevertheless, kitchen gardens and other household level approaches may often be possible, for example, using small quantities of waste water.

The potential components of food-based programs

There is 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 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. Dietary diversity alone may achieve this, but it is complex to measure; Nair et al review a dozen published systems for doing so (Nair, Augustine, and Konapur 2015). While dietary diversity may increase the intake of both energy and nutrients (Deckelbaum et al. 2006), some research suggests that diets must include retinol-rich animal-source foods or household gardens must include high carotene plant foods to be effective in improving vitamin A status (Shankar et al. 1998).

The most commonly implemented food-based approaches (again, excluding fortification) include one or more of 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
- Conventional plant breeding or genetic manipulation to increase provitamin A in plants
- Supplementation with leaf concentrate

Designing food-based approaches

Due to their complexity, food-based approaches tend to require time, patience, exploratory research, process evaluation, and the flexibility to make mid-term course corrections to be optimally 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 as well as nutrition and behavior change 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), (FAO and ILSI 1997), and (Underwood and Smitasiri 1999) for more details regarding the planning process.

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, taking also into account some of the broader cultural issues described in (Kuhnlein and Pelto 1997).

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

Animal foods are too expensive to offer a useful strategy for improving vitamin A status in deficient communities. An exception, in communities where it is available and acceptable, is liver. It is such a concentrated source of vitamin A that 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).

There are many challenges in devising approaches for meeting community vitamin A needs via plant sources. If no animal sources of retinol are consumed (keeping in mind that in low-income communities, breast does usually provide some, often to about 3 years of age), about 6mg/d of β-carotene (or equivalent amounts of other carotenes) is required, but typical intakes in European diets are only about 1-2 mg/d (Grune et al. 2010). In addition, Grune et al document that there are great differences in conversion in different situations, with substantial numbers of people converting carotene to retinol poorly. Measuring conversion rates is complicated by the fact that people with poor vitamin A status convert better and the larger the dose the lower the conversion rate (Novotny et al. 2010).

Increasing local production is particularly effective in lowering the price of foods that are too perishable to be marketed distant from where they are grown, although to date evidence is at best mixed for animal foods (Leroy and Frongillo 2007). Large-scale food-based programs 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, there is evidence that they continue to function, at least partially, even once external funding has been withdrawn (Hussain and Kvåle 1996),(Kidala, Greiner, and Gebre-Medhin 2000), (Faber et al. 2011). From the perspective of the host nation and particularly to communities and families that benefit from them, the net money costs of food-based approaches may be small or even negative in the sense that people can earn money by selling part of their harvest.

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 different 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).

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 does. Drying directly in the sun can completely destroy vitamin A, as in one fish variety tested in Bangladesh (Roos et al. 2002). In Thailand, candying of mango and papaya resulted in an 18% loss of beta-carotene, increasing up to a 30-40% loss after 3 months storage (Chavasit et al. 2002), but pickling of Pak Sien and Chinese green cabbage actually increased beta carotene by 30%. Three-month storage of fresh whole pumpkin in the shade led to a 12-fold increase in beta-carotene concentration.

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 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 have an impact even by itself

(Yusuf and Islam 1994). Special efforts must also be made to protect, support and promote breastfeeding because failure to breastfeed optimally can result in severe VAD, even in countries where diets are generally adequate (Wasantwisut, Chittchang, and Sinawat 2000).

Experience suggests that vulnerable groups can and will increase consumption of vitamin A rich foods in response to well-designed communication campaigns (FAO and ILSI 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 cause rapid price swings, depressing either consumer or local farmer interest in these foods (Greiner and Mitra 1995). Agricultural interventions with no communication 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).

Locally varying constraints to increased levels of home gardening

Kuhnlein outlines some easily overlooked cultural issues (Kuhnlein 2000) in planning food-based interventions like home gardening. 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.

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 failure 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.” However, if maintained for a long enough period to learn lessons and 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. 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 identified difficulties in obtaining (Zimbabwe) and maintaining (Bangladesh) fencing as the single greatest constraint. In both cases capital investment costs were the major entry barrier. 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 and to warn children where not to play. The solution found was for an agronomics expert to study each locale and to identify in each ecological niche which wild plants could best be utilized as (free) live fences, based on a number of criteria (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.

Poor carotene bioavailability

The absorption and bioconversion of the various provitamin A carotenoids into retinol are quite complex (Haskell 2012). Species, variety/cultivar, color intensity, ripeness, and storage all can be influential but so are geographic location, season, temperature, solar radiation, and cultivation practices (Ali and Tsou 2000),(Maiani et al. 2009).

The factor of greatest importance is the vitamin A status of the person consuming the food (Ribaya-Mercado et al. 2000). 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.

Small amounts of simultaneously consumed fat can greatly enhance the absorption of carotenoids. 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 absorption level achieved in healthy men from beadlets alone (Huang et al. 2000).

Stir frying carrots yields 6.5 times as much retinol equivalent as eating them raw (Ghavami, Coward, and Bluck 2012), as does consuming raw carrots with fresh avocado (providing 23g lipid) (Kopec et al. 2014). 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). Thus frying in fat, while causing heat losses, typically more than compensates for this by increasing bioavailability (Gomes et al. 2013). Carotenes dissolved in fat, as is the case in many fruits, have the highest level of absorption (de Pee, West, et al. 1998).

Some common household food preparation methods can decrease the total amount of carotenoids that are bioavailable from a given quantity of food (Chittchang 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 (Narasinga Rao 2000).

However, other common household cooking methods increase carotene bioavailability. The most important provitamin A carotenoids are heat stable at most cooking temperatures (60-100 degrees C) (Khachik et al. 1992). Chopping, especially grating, and then cooking actually tends to increase bioavailability (Castenmiller and West

1998), by anywhere 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 above 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). No loss of beta-carotene was observed in grated orange sweet potatoes allowed to stand for 4 hours (van Jaarsveld et al. 2006). The total carotenoids in pumpkin increased by 9% when boiled and 19% when steamed (Carvalho et al. 2014).

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). Thus helminth infection can have a large impact at population level, leading to speculation that it 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. 1998). 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). In one program evaluation, the higher infestation levels in the intervention area appeared to be responsible for the failure to have an impact (Kidala, Greiner, and Gebre-Medhin 2000).

The impact of food-based interventions

Evaluating the impact of food-based programs is challenging. First, there are many different types with unequal emphasis on the various components (Faber et al. 2001); (Kidala, Greiner, and Gebre-Medhin 2000); (Greiner and Mitra 1995). Since a large range of beneficial outcomes can accrue from implementing such programs, a wide range have also been studied, making them nearly impossible to compare. Though they are expensive to implement, and many have methodological weaknesses, Ionnatti et al (Ionnatti, Cunningham, and rUel 2009) conclude that such evaluations provide consistent and plausible evidence of impact on many factors such as consumption that are likely to lead to improvements in nutritional status over time. The first reviews of such studies published after 1992 (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, Krasevec, and FitzGerald 2004), (Masset et al. 2011), (Arimond et al. 2011), and (Girard et al. 2012).

Table 2 summarizes various outcomes found from evaluations of food-based interventions that have been reported since 1992. These are often called effectiveness studies. Most are outcome or impact evaluations. 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. Like for Table 1, the net changes indicated in Table 2 have been calculated from data available in the papers and were not tested for significance.

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

Reference	Location	Target Group	N	Intervention and duration	Impact on consumption	Impact on vitamin A status in $\frac{\mu}{mol}/L^a$	Other impacts
(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		
(Aphane, Pilime, and Saronga 2011)	Lesotho	Families with HIV-infected members	62 villages	Promoting and assisting families to build and cultivate keyhole gardens (in	Increased community production of vegetables from 10%		

				addition to other interventions)	- >20% of their needs.		
(Ayalew, Gebriel, and Kassa 1999)	3 districts in Ethiopia	Young children	Intervention: 500 families; 214 sampled	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)	
(CARE Nepal 1995)[b]	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
(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 consumption increased by 15g/d; high carotene fruits increased by 7.5g/d (no control group)	Xerosis decreased from 6.4 to 3.5%; Bitot spots from 2.8 to 0.8%; and XN from 15.3 to 4.7%	Knowledge increased about the importance of vitamin A and which foods contain it
(de Brauw et al. 2015)	Uganda and Mozambique	Children 6-35 mo Moz; 3-5 yr Uga	409 Moz; 481 Uga	distribute OFSP vines, train households to grow OFSP, and disseminate the health benefits of vitamin A; 2 yr	Intake of vitamin A: Mozambique net increase ~270 RAE; Uganda net increase ~460 RAE		
(De Pee, Bloem, et al. 1998)	Indonesia	Women and young children	~5000	Social marketing of eggs and DGLV over 1 yr	Eggs in past week among women increased from 80-92%; young children 78-92%; vegetables increased from 93-111g/person/d	SR increased with increased vitamin A intakes	Vitamin A intake increased from 335-371 RE/d for mothers and 130-160 RE/d for children

(Delisle et al. 2001)	Kaya District, Burkina Faso	Women and children <5 yr	10,000 for intervention; ~400 for study	Social marketing of red palm oil, 1 yr	Vitamin A intake: mothers increased from ~140-570 and children from ~60-3500 μg RE/day		
(English and Badcock 1998)	Vietnam	Mothers, children <5	5600 HH, 2 yr	Promoting HH gardening (VAC system); nutrition education	Doubled children's vitamin A intake (100 RE) compared to control area (50 RE)		
(Faber et al. 2011)	Ndunakazi Village, South Africa	Children 2-5 yr	Not specified	Promotion of home gardening, nutrition education; 20 mo		VAD (SR<20mcg/dl) declined from 58% to 34%	Increased maternal knowledge; 10% diarrhea in past 2 wk compared to 22% in control village
(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	
(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		
(Greiner and Mitra 1995)	All rural people in entire district of Gaibandah, Bangladesh	Young children	~2500 in intervention district; ~2500 in control district	Complex integrated set of behavior change, school, and household gardening interventions; evaluation measured impact of the third year of a 3-yr project	Net increase of 22.2% of households consuming green vegetables; 18.9% net increase among young children;	No significant impact on prevalence of XN	

(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		
(Hotz et al. 2011)	Mozambique	144 villages	400+ children 3-35 mo, 3-5.5 yr, and 260 women	Provision of ag extensionists (1:1200 pop) and nutr extensionists (1:960)+volunteer promoters. Free vines, nutrition education, media support. Model 1=1yr	Net increases of 263, 254 and 492 mg retinol activity equivalents/d) among the younger children, older children and women, respectively (Results were similar for a less intensive 3 yr project)		
(Hotz et al. 2012)	Uganda	Children 3-5 y/o in 3 districts	>1000 intervention+ control	2 yr; distribution of 20 free OFSP vines/HH; agric, nutr and marketing education; establishment of district marketing stalls; less intense in yr 2	Net increase in OFSP intake, net increase in vitamin A in all non-breastfed groups; net decrease in those w inadequate vitamin A intake except children 3-5		
"	Uganda	Children 6-35 mo; 3-5 y/o and women in 3 districts	>1000 intervention+ control	2 yr; distribution of 20 free OFSP vines/HH; agriculture, nutrition and marketing education; establishment of district marketing stalls; equally intense in yr 2	Net increase in OFSP intake; net increase in vitamin A in all non-breastfed groups; net decrease in those with 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

(Jones and de Brauw 2015)	Mozambique	<5s in 36 villages	553	seed systems, demand creation, and marketing for OFSP			Net reduction of diarrhea in <5s by 11% in past 2 wk. No impact on fever or respiratory tract infections
(Kidala, Greiner, and Gebre-Medhin 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 intervention area consumed vitamin A rich foods in past wk compared to 36% in control area	In post-intervention sampling, higher SR in control area (19.4 vs 14.0 mcg/dl) but higher with greater vegetable consumption (r=0.21) and in those with no helminths 24.0 vs. 12.3 mcg/dl	Had a home garden: 67% intervention vs 31% control; has and still uses solar drier: 43% (of 44% who received them) vs 0%; grows carotene-rich crops: 67% vs 28%
(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 intake by men and women but not children		
"	"	Jessore subdistrict	448 HH	Leasing of ponds to women's groups 3 yr before survey	No impact		
"	"	3 subdistricts in Mymensingh	380 HH	Training and credit to HH already owning ponds 6yr before survey	Increased vitamin A by men and women, not children		
(Laurie and Faber 2008)	South Africa	7 villages in Eastern Cape	219 HH (controls: 223 non-particip	3 yr, nutrition education, demonstration gardens in each village, training of agricultural extension agents	Increased frequency of consumption by children of 4 high-carotene foods; NS for 2 other high-carotene foods		Lower self-reported morbidity in 2 weeks prior to survey (statistically

			ating neighb ors)				significant differences in 6 of 7 symptoms); more HH cultivated vegetables
(Low et al. 2007)	Mozambique	Drought-prone province with ~10% HDVAC coverage	827 HH	2 exp districts and 1 control; 2 yr; promoting production and consumption of OFSP	Net 32% increase in children consuming during secondary harvest; 370RAE[c]/d greater retinol intake post intervention	Net 0.076 change in SR, 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
(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		
(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		
(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
(Parlato 1996)	Tahoua Province, Niger		Interve ntion 250,00 0	3 yr, social market campaign promoting increased consumption of liver as a snack food, wild DGLV, yellow squash and	Consumption of liver in previous week by women increased from 43-73%; for children from 37-49%; for DGLV,		

				mango by women and children and increased dry season production of DGLV	children, from 57-94%; feeding DGLV at 6 mo of age increased from 52-59%		
(Phillips et al. 1996)	2 departments in Guatemala	Women of childbearing age and children <6	1.2 million population	HOPE project promoting increased production (providing seed for home gardens) and consumption of high provitamin A foods, evaluated after 3 yr		Those without gardens were 3.5 times more likely to have children with VAD controlling for several confounders	85% adopted home gardens
(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)		
"	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)		
(Rajasekaran 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		
(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)

(Solon et al. 1996)	Cagayan de Oro Philippines	Young children, pregnant and lactating women	Int: 400,000; survey 300	Promotion of production and consumption of 5 provitamin A rich vegetables via mass media (3 mo) and community and school outreach (5 mo)	Household consumption of 3 of the 5 increased >25%, 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		
(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 spots compared to 6% participating for 3 yr (NS)	HH growing carotene-rich foods increased from 10% to 65%; increase in knowledge of cause of night blindness 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 declined from 5.4 to 3.2% from 1987 to 1990 (no control)	Nearly 1 million home gardens were developed
(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 night blind children decreased from 68 (4.1%) to 5 (0.47%) (no control)	
(Zagré et al. 2003)	Kaya District, Burkina Faso	Women and	10,000 for interve	Social marketing of red palm oil, 2 yr	Mothers' vitamin A intake increased from ~235-655 and	Rates of serum retinol,<0.70 mmol/l decreased	

		children <5 yr	ntion; 210 for study		children from ~164-514 μg RE/day	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	

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. Based on data in (Berti, Krasevec, and FitzGerald 2004)

Table Abbreviations

d=day
DGLV=dark green leafy vegetables
F&V=fruits and vegetables
g=gram
HDVAC=high dose vitamin A capsule
HH = households
HKI=Helen Keller International
ICDDR,B=International Centre for Diarrheal Disease Control, Bangladesh
mo=month
NS = not significant
OFSP = orange-fleshed sweet potato
RAE=retinol activity equivalent
RE=retinol equivalent
SR = serum retinol
VAC= *Vuon*, garden or orchard, *Ao*, fish pond, and *Chuong*, pigsty or poultry shed—home agricultural system in Vietnam
wk=week
yr=year
XN=nightblindness
“=ditto (identical to box above)
~=approximately equal to
μ=microgram

Table 2 reports on the impact of 40 interventions, that is, impact evaluations or effectiveness trials; in a few cases one publication reports on two or three intervention impact results and in one case more than one publication reported on the same evaluation, but these interventions are basically reported on in 34 publications. Changes in consumption, vitamin A status, and other indicators are reported on. Summarizing the results is complex because different foods and different population groups are reported on. 13 interventions reported increases in production of high-carotene foods and none reported lack of increase or reductions. 64 positive results are reported regarding consumption with 9 results where there was no significant change and 1 in which there was a decrease in consumption. There were 17 reports for 12 studies of variously measured improvements in vitamin A status and 2 with no change. While more diverse than the results presented for efficacy trials in Table 1, the presentation of this many results may assist in planning the evaluation of future food-based interventions.

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 years 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 factors that contribute to success (Finley and Darnton-Hill 2001).

Policy alternatives

Supplementation programs reach 5-10% of the entire population, focusing on the group (young children) most vulnerable to mortality due to vitamin A deficiency. Yet vitamin A deficiency may have consequences for other groups that they ignore, especially pregnant and lactating women. Because they are rarely measured and yet sometimes are found to have alarmingly poor vitamin A status (Ncube, Malaba, et al. 2001), 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. 2010). Yet, as reviewed by Mason et al (Mason et al. 2015), the impact of supplementation on VAD is small and transient and even its impact on mortality no longer appears to be substantial. Some evidence is emerging that for a given sex of the child, it may be dangerous to provide certain vaccinations at the same time as high-dose vitamin A capsules (Fisker and Greiner 2017).

Supplementation approaches, through both active and passive mechanisms, have inhibited the implementation of other approaches (Latham 2010), (Greiner 2012). While this is based on anecdotal evidence (since no one has done a relevant survey of policymakers), hardly any countries have adopted any other national level programming to reduce vitamin A deficiency beyond a few that mandate vitamin A fortification. (Even this may not impact the lower income groups that do not purchase the fortified foods.) It is hard to imagine that so little would have been done over the past 25 years if governments and donor agencies did not believe they had the supplementation program “to fall back on”. Approaches for actively but safely replacing supplementation programs with more effective and sustainable ones are thus the only viable long-term policy alternative.

One of several approaches to begin with (Greiner 2012) might be shifting to disease-based HDVAC distribution. HDVAC 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.

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 district by district, as salt fortification became available (Peterson et al. 1999) based on simplified dietary assessment techniques (Sloan et al. 1997), (Omidvar et al. 2002) and sample testing of biochemical indicators. Mandatory national 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.

Food-based approaches, using local foods, can be designed to be affordable and sustainable. Linear programming may help in the planning stages (Raymond et al. 2017). Food based approaches cannot easily solve all vitamin A and other nutritional problems in all places at all times. In places suffering from serious climate threats, very poor soils, or in conflict zones, additional constraints may exist. Production at household level may be the only option available, which, in addition to the simultaneous behavior change programs needed where dietary change is required, may require large, long-term investments. Nevertheless, given their low net per capita costs and potential for sustainability, they deserve attention in nearly all settings.

References

Aguayo, V. M., S. Kahn, C. Ismael, and S. Meershoek. 2005. "Vitamin A deficiency and child mortality in Mozambique." *Public Health Nutr* 8 (1):29-31.

Ahmed, Mohamed M., Mohammed Jabbar, and Simeon Ehui. 2000. "Household-level economic and nutritional impacts of market-oriented dairy production in the Ethiopian highlands." *Food & Nutrition Bulletin* 21 (4):460-465.

Ali, Mubarik, and Samson Tsou. 2000. "The integrated research approach of the Asian Vegetable Research and Development Center (AVRDC) to enhance micronutrient availability." *Food & Nutrition Bulletin* 21 (4):472-481.

Andersson, A. 1994. A study on small-scale vegetable gardening with special focus on live fences. Uppsala, Sweden: Swedish University of Agricultural Sciences, International Rural Development Centre.

Aphane, JM, N Pilime, and NJ Saronga. 2011. "Food-based, Low-cost Strategies to Combat Micronutrient Deficiencies: Evidence-based Interventions in Lesotho." In *Combating Micronutrient Deficiencies: Food-Based Approaches*, edited by B. Thompson and L. Amoroso, 92-116. Oxfordshire, UK: Cabi.

Arimond, M, C Hawkes, MT Ruel, Z Sifri, PR Berti, J Leroy, JW Low, LR Brown, and EA Frongillo. 2011. "Agricultural interventions and nutrition: Lessons from the past and new evidence." In *Combating micronutrient deficiencies: food-based approaches*, edited by B. Thompson and L. Amoroso, 41-75. Oxfordshire, UK: Cabi.

Ayalew, W., Z.W. Gebriel, and H. Kassa. 1999. Reducing Vitamin A Deficiency in Ethiopia: Linkages with a Women-Focused Dairy Goat Farming Project. Washington, DC: International Center for Research on Women.

Balcha, Haile Meskel. 2001. "Experience of World Vision Ethiopia Micronutrient Program in promoting the production of vitamin Arich foods." *Food & Nutrition Bulletin* 22 (4):366-369.

Barrett, Christopher B, and Leah EM Bevis. 2015. "The micronutrient deficiencies challenge in African Food Systems." In *The fight against hunger and malnutrition: the role of food, agriculture, and targeted policies*, edited by David E. Sahn, 61-88. Oxford: Oxford University Press.

Bengtsson, A., A. Namutebi, M.L. Alminger, and U. Svanberg. 2008. "Effects of various traditional processing methods on the all-< i> trans</i>-< i> β</i>-carotene content of orange-fleshed sweet potato." *Journal of Food Composition and Analysis* 21 (2):134-143.

Berti, P.R., J. Krasevec, and S. FitzGerald. 2004. "A review of the effectiveness of agriculture interventions in improving nutrition outcomes." *Public Health Nutrition* 7 (05):599-609.

Blaney, Sonia, Micheline Beaudry, and Michael Latham. 2009. "Contribution of natural resources to nutritional status in a protected area of Gabon." *Food & Nutrition Bulletin* 30 (1):49-62.

Bloem, M. W., N. Huq, J. Gorstein, S. Burger, T. Kahn, N. Islam, S. Baker, and F. Davidson. 1996. "Production of fruits and vegetables at the homestead is an important source of vitamin A among women in rural Bangladesh." *European Journal of Clinical Nutrition* 50:S62-S67.

Bogard, Jessica R., Shakuntala H. Thilsted, Geoffrey C. Marks, Md Abdul Wahab, Mostafa A. R. Hossain, Jette Jakobsen, and James Stangoulis. 2015. "Nutrient composition of important fish species in Bangladesh and potential contribution to recommended nutrient intakes." *Journal of Food Composition and Analysis* 42:120-133. doi: http://dx.doi.org/10.1016/j.jfca.2015.03.002.

Borlaug, N. 2007. "Feeding a hungry world." *Science* 318 (5849):359. doi: 10.1126/science.1151062.

Bouis, Howarth E. 2000. "Commercial vegetable and polyculture fish production in Bangladesh: Their impacts on household income and dietary quality." *Food & Nutrition Bulletin* 21 (4):482-487.

Brownrigg, L. 1985. Home gardening in international development: what the literature shows. Washington DC: League for International Food Education.

Brun, T., J. Reynaud, and S. Chevassusagnes. 1989. "FOOD AND NUTRITIONAL IMPACT OF ONE HOME GARDEN PROJECT IN SENEGAL." *Ecology of Food and Nutrition* 23 (2):91-108.

Bulux, J, J Quan de Serrano, A Giuliano, R Perez, C Y Lopez, C Rivera, N W Solomons, and L M Canfield. 1994. "Plasma response of children to short-term chronic beta-carotene supplementation." *The American Journal of Clinical Nutrition* 59 (6):1369-75.

Burton-Freeman, Britt M., and Howard D. Sesso. 2014. "Whole Food versus Supplement: Comparing the Clinical Evidence of Tomato Intake and Lycopene Supplementation on Cardiovascular Risk Factors." *Advances in Nutrition: An International Review Journal* 5 (5):457-485. doi: 10.3945/an.114.005231.

Bushamuka, Victor N., Saskia de Pee, Aminuzzaman Talukder, Lynnda Kiess, Dora Panagides, Abu Taher, and Martin Bloem. 2005. "Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh." *Food & Nutrition Bulletin* 26 (1):17-25.

Canfield, L. M., and R. G. Kaminsky. 2000. "Red palm oil in the maternal diet improves the vitamin A status of lactating mothers and their infants." *Food & Nutrition Bulletin* 21 (2):144-148.

Canfield, Louise M., Rina G. Kaminsky, Douglas L. Taren, Elysa Shaw, and Jay K. Sander. 2001. "Red palm oil in the maternal diet increases provitamin A carotenoids in breastmilk and serum of the mother-infant dyad." *European Journal of Nutrition* 40 (1):30-38. doi: 10.1007/PL00007383.

CARE Nepal. 1995. A study of the Evaluation of Home Gardening Program in Bajura and Mahottari Districts. Project Report. Kathmandu: CARE.

Carvalho, Lucia Maria Jaeger de, Lara de Azevedo Sarmet Moreira Smiderle, José Luiz Viana de Carvalho, Flavio de Souza Neves Cardoso, and Maria Gabriela Bello Koblitz. 2014. "Assessment of carotenoids in pumpkins after different home cooking conditions." *Food Science and Technology (Campinas)* 34:365-370.

Castenmiller, J. J. M., and C. E. West. 1998. "Bioavailability and bioconversion of carotenoids." *Annual Review of Nutrition* 18:19-38. doi: 10.1146/annurev.nutr.18.1.19.

Castenmiller, Jacqueline J. M., Clive E. West, Jozef P. H. Linssen, Karin H. van het Hof, and Alphons G. J. Voragen. 1999. "The Food Matrix of Spinach Is a Limiting Factor in Determining the Bioavailability of β-Carotene and to a Lesser Extent of Lutein in Humans." *The Journal of Nutrition* 129 (2):349-355.

Chadha, ML, LM Engle, J d'A Hughes, DR Ledesma, and KM Weinberger. 2011. "10 AVRDC–The World Vegetable Center's Approach to Alleviate Malnutrition." In *Combating Micronutrient Deficiencies: Food-Based Approaches*, edited by B. Thompson and L. Amoroso, 183-197. Oxfordshire, UK: Cabi.

Chakravarty, Indira. 2000. "Food-based strategies to control vitamin A deficiency." *Food & Nutrition Bulletin* 21 (2):135-143.

Chavasit, V., R. Pisaphab, P. Sungpuag, S. Jittinandana, and E. Wasantwisut. 2002. "Changes in β-Carotene and Vitamin A Contents of Vitamin A-rich Foods in Thailand During Preservation and Storage." *Journal of food science* 67 (1):375-379.

Chittchang, Uraiporn, Sitima Jittinandana, Pongtorn Sungpuag, Visith Chavasit, and Emorn Wasantwisut. 1999. "Recommending vitamin Arich foods in southern Thailand." *Food & Nutrition Bulletin* 20 (2):238-242.

Clydesdale, F. M., C. T. Ho, C. Y. Lee, N. I. Mondy, and R. L. Shewfelt. 1991. "THE EFFECTS OF POSTHARVEST TREATMENT AND CHEMICAL INTERACTIONS ON THE BIOAVAILABILITY OF ASCORBIC-ACID, THIAMIN, VITAMIN-A, CAROTENOIDS, AND MINERALS." *Critical Reviews in Food Science and Nutrition* 30 (6):599-638.

de Brauw, Alan , Patrick Eozenou, Daniel Gilligan, Christine Hotz, Neha Kumar, and J.V. Meenakshi. 2015. Biofortification, crop adoption, and health information: impact pathways in Mozambique and Uganda. Washington, D.C.: International Food Policy Research Institute (IFPRI).

de Pee, S., M. W. Bloem, R. Tjiong, E. Martini, Satoto, J. Gorstein, R. Shrimpton, and Muhilal. 1999. "Who has a high vitamin A intake from plant foods, but a low serum retinol concentration? Data from women in Indonesia." *Eur J Clin Nutr* 53 (4):288-97.

De Pee, S., M.W. Bloem, R. Satoto Yip, A. Sukaton, R. Tjiong, R. Shrimpton, and B. Muhilal Kodyat. 1998. "Impact of a social marketing campaign promoting dark-green leafy vegetables and eggs in Central Java, Indonesia." *International journal for vitamin and nutrition research* 68 (6):389-398.

de Pee, S., C. E. West, D. Permaesih, Martuti, Muhilal, and Jgaj Hautvast. 1998. "Orange fruit is more effective than are dark-green, leafy vegetables in increasing serum concentrations of retinol and beta-carotene in schoolchildren in Indonesia." *American Journal of Clinical Nutrition* 68 (5):1058-1067.

de Pee, S., C.E. West, Muhilal, D. Karyadi, and J.G.A.J. Hautvast. 1995. "Lack of improvement in vitamin A status with increased consumption of dark-green leafy vegetables." *Lancet* 346:75-81.

Deckelbaum, Richard J., Cheryl Palm, Patrick Mutuo, and Fabrice DeClerck. 2006. "Econutrition: Implementation models from the Millennium Villages Project in Africa." *Food & Nutrition Bulletin* 27 (4):335-342.

Delisle, H., ne, Zagr, No, and Virginie Ouedraogo. 2001. "Marketing of red palm oil as a food source of vitamin A in Burkina Faso: A pilot project involving women's groups." *Food & Nutrition Bulletin* 22 (4):388-394.

Drammeh, Bakary S., Grace S. Marquis, Ellen Funkhouser, Chris Bates, Isao Eto, and Charles B Stephensen. 2002. "A Randomized, 4-Month Mango and Fat Supplementation Trial Improved Vitamin A Status among Young Gambian Children." *The Journal of Nutrition* 132 (12):3693-3699.

Ecker, O., and M. Qaim. 2010. Analyzing nutritional impacts of policies, an empirical study for Malawi. In *IFPRI Discussion Paper*. Washington DC: International Food Policy Research Institute.

Egbi, G. , G.A. Alatiah, I. Ayi, and M. Steiner-Asiedu. 2017. "Red palm oil bean-stew improved serum vitamin a and haemoglobin concentrations and anthropometric indicators of school children with low vitamin A concentrations in a malaria-endemic setting." *Afr. J. Food Agric. Nutr. Dev.* 17 (4):12817-12836. doi: 10.18697/ajfand.80.16750.

Englberger, L., G. C. Marks, and M. H. Fitzgerald. 2004. "Factors to consider in Micronesian food-based interventions: a case study of preventing vitamin A deficiency." *Public Health Nutr* 7 (3):423-31.

Englberger, Lois. 2001. "Natural food sources of provitamin A that have previously been unrecognized." *Food & Nutrition Bulletin* 22 (1):99-101.

English, R M, and J Badcock. 1998. "A community nutrition project in Vietnam: effects on child morbidity." *Food, Agriculture and Nutrition (FAO)* 22:15-21.

English, R M, J C Badcock, Tu Giay, Tu Ngu, A-M Waters, and S A Bennett. 1997. "Effect of nutrition improvement project on morbidity from infectious diseases in preschool children in Vietnam: comparison with control commune." *BMJ* 315 (7116):1122-1125. doi: 10.1136/bmj.315.7116.1122.

Faber, M, SM Laurie, B Thompson, and L Amoroso. 2011. "A home gardening approach developed in South Africa to address vitamin A deficiency." In *Combating micronutrient deficiencies: food-based approaches.*, edited by B. Thompson and L. Amoroso, 163-182. Oxfordshire, UK: Cabi.

Faber, Mieke, Michael AS Phungula, Sonja L Venter, Muhammad A Dhansay, and AJ Spinnler Benadé. 2002. "Home gardens focusing on the production of yellow and dark-green leafy vegetables increase the serum retinol concentrations of 2–5-y-old children in South Africa." *The American Journal of Clinical Nutrition* 76 (5):1048-1054.

Faber, Mieke, and Paul J. van Jaarsveld. 2007. "The production of provitamin A-rich vegetables in home-gardens as a means of addressing vitamin A deficiency in rural African communities." *Journal of the Science of Food and Agriculture* 87 (3):366-377. doi: 10.1002/jsfa.2774.

Faber, Mieke, S. Venter, M. A. S. Phungula, Benad, and A. J. S. 2001. "An integrated primary health-care and provitamin A household food-production program: Impact on food-consumption patterns." *Food & Nutrition Bulletin* 22 (4):370-375.

FAO, and ILSI. 1997. Preventing micronutrient malnutrition: A guide to food-based approaches - A manual for policy makers and programme planners. Washington DC: International Life Sciences Institute.

Fiedler, J. L., F. Mubanga, W. Siamusantu, M. Musonda, K. F. Kabwe, and C. Zulu. 2014. "Child Health Week in Zambia: costs, efficiency, coverage and a reassessment of need." *Health Policy Plan* 29 (1):12-29. doi: 10.1093/heapol/czs129.

Finley, D'Ann, and Ian Darnton-Hill. 2001. "Report of Working Group 3: Promoting food-based approaches to eliminate vitamin A deficiency in Africa." *Food & Nutrition Bulletin* 22 (4):469-469.

Fisker, Ane B, and Ted Greiner. 2017. "High dose vitamin A capsules–Rusty bullets?" *World Nutrition* 8 (1):52-61. doi: https://doi.org/10.26596/wn.20178152-61.

Fungo, R., and M. Pillay. 2011. "beta-Carotene content of selected banana genotypes from Uganda." *African Journal of Biotechnology* 10 (28):5423-5430.

Gannon, Bryan, Chisela Kaliwile, Sara A Arscott, Samantha Schmaelzle, Justin Chileshe, Ngándwe Kalungwana, Mofu Mosonda, Kevin Pixley, Cassim Masi, and Sherry A Tanumihardjo. 2014. "Biofortified orange maize is as efficacious as a vitamin A supplement in Zambian children even in the presence of high liver reserves of vitamin A: a community-based, randomized placebo-controlled trial." *The American Journal of Clinical Nutrition* 100 (6):1541-1550. doi: 10.3945/ajcn.114.087379.

Ghavami, Abdollah, W. Andy Coward, and Les J. C. Bluck. 2012. "The effect of food preparation on the bioavailability of carotenoids from carrots using intrinsic labelling." *British Journal of Nutrition* 107 (09):1350-1366. doi: doi:10.1017/S000711451100451X.

Gibson, R.S., F. Yeudall, N. Drost, B.M. Mtitimuni, and T.R. Cullinan. 2003. "Experiences of a community-based dietary intervention to enhance micronutrient adequacy of diets low in animal source foods and high in phytate: a case study in rural Malawian children." *The Journal of Nutrition* 133 (11):3992S-3999S.

Gillespie, S., and J. Mason. 1994. Controlling Vitamin A Deficiency. In *Nutrition Policy Discussion Paper*. Geneva: Administrative Committee on Coordination, Subcommittee on Nutrition.

Girard, Amy Webb, Julie L. Self, Corey McAuliffe, and Olafunke Olude. 2012. "The Effects of Household Food Production Strategies on the Health and Nutrition Outcomes of Women and Young Children: A Systematic Review." *Paediatric and Perinatal Epidemiology* 26:205-222. doi: 10.1111/j.1365-3016.2012.01282.x.

Gomes, Suellen, Alexandre Guedes Torres, Ronoel Godoy, Sidney Pacheco, José Carvalho, and Marília Nutti. 2013. "Effects of Boiling and Frying on the Bioaccessibility of β-Carotene in Yellow-Fleshed Cassava Roots (Manihot Esculenta Crantz cv. BRS Jari)." *Food and Nutrition Bulletin* 34 (1):65-74. doi: 10.1177/156482651303400108.

Graham, Robin D., and Julia M. Rosser. 2000. "Carotenoids in staple foods: Their potential to improve human nutrition." *Food & Nutrition Bulletin* 21 (4):404-409.

Greiner, T. 1997. "Rapid appraisal before impact evaluation studies." *World Health Forum* 18 (1):66-7.

Greiner, T. 2012. "Vitamin A Wars: the Downsides of Donor-driven Aid." Independent Science News, Last Modified September 25, 2012, accessed January 21. http://independentsciencenews.org/health/vitamin-a-wars-the-downsides-of-donor-driven-aid/.

Greiner, T., and M.A. Mannan. 1999. " Increasing micronutrient intakes in rural Bangladesh: An NGO's search for sustainability." In *Scaling Up and Scaling Down: Overcoming Malnutrition in Developing Countries*, edited by T. Marchione, 157-177. London: Gordon and Breach.

Greiner, T., and S.N. Mitra. 1995. "Evaluation of the impact of a food-based approach to solving vitamin A deficiency in Bangladesh." *Food and Nutrition Bulletin* 16 (3):193-205.

Grubben, Gerard, Wijnand Klaver, R. Non-Womdim, A. Everaarts, L. Fondio, J.A. Nugteren, and M. Corrado. 2014. "Vegetables to combat the hidden hunger in Africa." *Chronica Horticulturae* 54:24-32.

Grune, Tilman, Georg Lietz, Andreu Palou, A. Catharine Ross, Wilhelm Stahl, Guangweng Tang, David Thurnham, Shi-an Yin, and Hans K. Biesalski. 2010. "β-Carotene Is an Important Vitamin A Source for Humans." *The Journal of Nutrition* 140 (12):2268S-2285S. doi: 10.3945/jn.109.119024.

Hagenimana, Vital, Jan Low, Mary Anyango, Kathleen Kurz, Simon T. Gichuki, and Jackson Kabira. 2001. "Enhancing vitamin A intake in young children in western Kenya: Orange-fleshed sweet potatoes and women farmers can serve as key entry points." *Food & Nutrition Bulletin* 22 (4):376-387.

Haskell, M. J. 2012. "The challenge to reach nutritional adequacy for vitamin A: beta-carotene bioavailability and conversion-evidence in humans." *American Journal of Clinical Nutrition* 96 (5):1193S-1203S. doi: 10.3945/ajcn.112.034850.

Haskell, M. J., P. Pandey, J. M. Graham, J. M. Peerson, R. K. Shrestha, and K. H. Brown. 2005. "Recovery from impaired dark adaptation in nightblind pregnant Nepali women who receive small daily doses of vitamin A as amaranth leaves, carrots, goat liver, vitamin A-fortified rice, or retinyl palmitate." *American Journal of Clinical Nutrition* 81 (2):461-471.

Haskell, Marjorie J, Kazi M Jamil, Ferdaus Hassan, Janet M Peerson, M Iqbal Hossain, George J Fuchs, and Kenneth H Brown. 2004. "Daily consumption of Indian spinach (Basella alba) or sweet potatoes has a positive effect on total-body vitamin A stores in Bangladeshi men." *The American Journal of Clinical Nutrition* 80 (3):705-714.

Helen Keller International--Asia-Pacific. 2010. "Homestead food production model contributes to improved household food security, nutrition and female empowerment – Experience from scaling-up programs in Asia (Bangladesh, Cambodia, Nepal and Philippines)." *APRO Nutrition Bulletin* 8 (1):1-8.

Hof, K. H. V., C. E. West, J. A. Weststrate, and Jgaj Hautvast. 2000. "Dietary factors that affect the bioavailability of carotenoids." *Journal of Nutrition* 130 (3):503-506.

Hotz, Christine, Cornelia Loechl, Alan de Brauw, Patrick Eozenou, Daniel Gilligan, Mourad Moursi, Bernardino Munhaua, Paul van Jaarsveld, Alicia Carriquiry, and J. V. Meenakshi. 2011. "A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women." *British Journal of Nutrition* 108 (1):163-176. doi: 10.1017/S0007114511005174.

Hotz, Christine, Cornelia Loechl, Abdelrahman Lubowa, James K. Tumwine, Grace Ndeezi, Agnes Nandutu Masawi, Rhona Baingana, Alicia Carriquiry, Alan de Brauw, Jonnalagadda V. Meenakshi, and Daniel O. Gilligan. 2012. "Introduction of β-Carotene–Rich Orange Sweet Potato in Rural Uganda Resulted in Increased Vitamin A Intakes among Children and Women and Improved Vitamin A Status among Children." *The Journal of Nutrition* 142 (10):1871-1880. doi: 10.3945/jn.111.151829.

Huang, Ching-jang, Ya-Li Tang, Ching-Yu Chen, Mei-Ling Chen, Cherh-Huei Chu, and Chin-Tou Hseu. 2000. "The Bioavailability of β-Carotene in Stir- or Deep-Fried Vegetables in Men Determined by Measuring the Serum Response to a Single Ingestion." *The Journal of Nutrition* 130 (3):534-540.

Hussain, A., and G. Kvåle. 1996. "Sustainability of a nutrition education programme to prevent night-blindness in Bangladesh." *Tropical Medicine and International Health* 1 (1):43-53.

Ionnatti, L., K. Cunningham, and M. rUel. 2009. Improving diet quality and micronutrient nutrition, homestead food production in Bangladesh. In *IFPRI Discussion Paper*. Washington, DC: International Food Policy Research Institute.

Jacobs, D. R., and L. C. Tapsell. 2007. "Food, not nutrients, is the fundamental unit in nutrition." *Nutrition Reviews* 65 (10):439-450. doi: 10.1301/nr.2007.oct.439-450.

Jalal, F., M. C. Nesheim, Z. Agus, D. Sanjur, and J. P. Habicht. 1998. "Serum retinol concentrations in children are affected by food sources of beta-carotene, fat intake, and anthelmintic drug treatment." *American Journal of Clinical Nutrition* 68 (3):623-629.

Jamil, Kazi M., Kenneth H. Brown, Maleka Jamil, Janet M. Peerson, Alison H. Keenan, John W. Newman, and Marjorie J. Haskell. 2012. "Daily Consumption of Orange-Fleshed Sweet Potato for 60 Days Increased Plasma β-Carotene Concentration but Did Not Increase Total Body Vitamin A Pool Size in Bangladeshi Women." *The Journal of Nutrition* 142 (10):1896-1902. doi: 10.3945/jn.112.164830.

Jones, Kelly M., and Alan de Brauw. 2015. "Using Agriculture to Improve Child Health: Promoting Orange Sweet Potatoes Reduces Diarrhea." *World Development* 74:15-24. doi: http://dx.doi.org/10.1016/j.worlddev.2015.04.007.

Kehoe, Sarah H., Harsha Chopra, Sirazul A. Sahariah, Dattatray Bhat, Renuka P. Munshi, Falguni Panchal, Stephen Young, Nick Brown, Dnyaneshwar Tarwande, Meera Gandhi, Barrie M. Margetts, Ramesh D. Potdar, and Caroline H. D. Fall. 2015. "Effects of a food-based intervention on markers of micronutrient status among Indian women of low socio-economic status." *British Journal of Nutrition* 113 (5):813-821. doi: 10.1017/S000711451400419X.

Khachik, Frederick, Mudlagiri B. Goli, Gary R. Beecher, Joanne Holden, William R. Lusby, Maria D. Tenorio, and Mercedes R. Barrera. 1992. "Effect of food preparation on qualitative and quantitative distribution of major carotenoid constituents of tomatoes and several green vegetables." *Journal of Agricultural and Food Chemistry* 40 (3):390-398. doi: 10.1021/jf00015a006.

Khan, Nguyen Cong, Clive E West, Saskia de Pee, Diane Bosch, Ha Do Phuong, Paul JM Hulshof, Ha Huy Khoi, Hans Verhoef, and Joseph GAJ Hautvast. 2007. "The contribution of plant foods to the vitamin A supply of lactating women in Vietnam: a randomized controlled trial." *The American Journal of Clinical Nutrition* 85 (4):1112-1120.

Kidala, D., T. Greiner, and M. Gebre-Medhin. 2000. "Five-year follow-up of a food-based vitamin A intervention in Tanzania." *Public Health Nutr* 3 (4):425-31.

Kidmose, U., L. P. Christensen, S. M. Agill, and S. H. Thilsted. 2007. "Effect of home preparation practices on the content of provitamin A carotenoids in coloured sweet potato varieties (Ipomoea batatas Lam.) from Kenya." *Innovative Food Science & Emerging Technologies* 8 (3):399-406. doi: 10.1016/j.ifset.2007.03.025.

Kongsbak, Katja, Shakuntala H. Thilsted, and Mohammed A. Wahed. 2008. "Effect of consumption of the nutrient-dense, freshwater small fish Amblypharyngodon mola on biochemical indicators of vitamin A status in Bangladeshi children: a randomised, controlled study of efficacy." *British Journal of Nutrition* 99 (03):581-597. doi: doi:10.1017/S000711450781912X.

Kopec, Rachel E., Jessica L. Cooperstone, Ralf M. Schweiggert, Gregory S. Young, Earl H. Harrison, David M. Francis, Steven K. Clinton, and Steven J. Schwartz. 2014. "Avocado Consumption Enhances Human Postprandial Provitamin A Absorption and Conversion from a Novel High–β-Carotene Tomato Sauce and from Carrots." *The Journal of Nutrition* 144 (8):1158-1166. doi: 10.3945/jn.113.187674.

Krause, Vivian M., Helene Delisle, and Noel W. Solomons. 1998. "Fortified Foods Contribute One Half of Recommended Vitamin A Intake in Poor Urban Guatemalan Toddlers." *The Journal of Nutrition* 128 (5):860-864.

Kuhnlein, H.V., and G.H. Pelto. 1997. *Culture, environment and food to prevent vitamin A deficiency*: International Development Research.

Kuhnlein, Harriet V. 2000. "Finding food sources of vitamin A and provitamin A." *Food & Nutrition Bulletin* 21 (2):130-134.

Kumar, N., and A.R. Quisumbing. 2010. Access, adoption and diffusion. Understanding the long-term impacts of improved vegetable and fish technologies in Bangladesh. In *IFPRI Discussion Papers*. Washington DC: International Food Policy Research Institute.

Lartey, Anna, Alhassan Manu, Kenneth H Brown, Janet M Peerson, and Kathryn G Dewey. 1999. "A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age." *The American Journal of Clinical Nutrition* 70 (3):391-404.

Latham, M. . 2010. "The great vitamin A fiasco. [Commentary]." *World Nutrition* 1 (1):12-44.

Laurie, Sunette M., and Mieke Faber. 2008. "Integrated community-based growth monitoring and vegetable gardens focusing on crops rich in β-carotene: Project evaluation in a rural community in the Eastern Cape, South Africa." *Journal of the Science of Food and Agriculture* 88 (12):2093-2101. doi: 10.1002/jsfa.3319.

Lechtig, A., G. Cornale, M. E. Ugaz, and L. Arias. 2009. "Decreasing stunting, anemia, and vitamin A deficiency in Peru: Results of The Good Start in Life Program." *Food and Nutrition Bulletin* 30 (1):37-48.

Leroy, Jef L., and Edward A. Frongillo. 2007. "Can Interventions to Promote Animal Production Ameliorate Undernutrition?" *The Journal of Nutrition* 137 (10):2311-2316.

Lichtenstein Ah, Russell R. M. 2005. "Essential nutrients: Food or supplements?: where should the emphasis be?" *JAMA* 294 (3):351-358. doi: 10.1001/jama.294.3.351.

Lietz, Georg, C Jeya K Henry, Generose Mulokozi, Joseph KL Mugyabuso, Angelina Ballart, Godwin D Ndossi, Wilbald Lorri, and Andrew Tomkins. 2001. "Comparison of the effects of supplemental red palm oil and sunflower oil on maternal vitamin A status." *The American Journal of Clinical Nutrition* 74 (4):501-509.

Low, Jan W., Mary Arimond, Nadia Osman, Benedito Cunguara, Filipe Zano, and David Tschirley. 2007. "A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Serum Retinol Concentrations in Young Children in Rural Mozambique." *The Journal of Nutrition* 137 (5):1320-1327.

Mahapatra, S, and R Manorama. 1997. "The protective effect of red palm oil in comparison with massive vitamin A dose in combating vitamin A deficiency in Orissa, India." *Asia Pacific J Clin Nutr* 6 (4):246-250.

Maiani, Giuseppe, María Jesús Periago Castón, Giovina Catasta, Elisabetta Toti, Isabel Goñi Cambrodón, Anette Bysted, Fernando Granado-Lorencio, Begoña Olmedilla-Alonso, Pia Knuthsen, Massimo Valoti, Volker Böhm, Esther Mayer-Miebach, Diana Behsnilian, and Ulrich Schlemmer. 2009. "Carotenoids: Actual knowledge on food sources, intakes, stability and bioavailability and their protective role in humans." *Molecular Nutrition & Food Research* 53 (S2):S194-S218. doi: 10.1002/mnfr.200800053.

Makhotla, Likeleli, and Sheryl Hendriks. 2004. "Do home gardens improve the nutrition of rural pre-schoolers in Lesotho?" *Development Southern Africa* 21 (3):575-581. doi: 10.1080/0376835042000265496.

Manorama, R, M Sarita, and C Rukmini. 1997. "Red palm oil for combating vitamin A deficiency." *Asia Pacific J Clin Nutr* 6 (1):56-59.

Martin, J., D. W. T. Crompton, E. Carrera, and M. C. Nesheim. 1984. "MUCOSAL SURFACE LESIONS IN YOUNG PROTEIN-DEFICIENT PIGS INFECTED WITH ASCARIS-SUUM (NEMATODA)." *Parasitology* 88 (APR):333-&.

Mason, J., T. Greiner, R. Shrimpton, D. Sanders, and J. Yukich. 2015. "Vitamin A policies need rethinking." *Int J Epidemiol* 44 (1):283-92. doi: 10.1093/ije/dyu194.

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. 2012. "Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review." *BMJ* 344. doi: 10.1136/bmj.d8222.

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. 2011. A systematic review of agricultural interventions that aim to improve nutritional status of children. London: EPPI-Centre, Social Science Research Institute, Institute of Education, University of London.

Meenakshi, J. V., Nancy L. Johnson, Victor M. Manyong, Hugo DeGroote, Josyline Javelosa, David R. Yanggen, Firdousi Naher, Carolina Gonzalez, James García, and Erika Meng. 2010. "How Cost-Effective is Biofortification in Combating Micronutrient Malnutrition? An Ex ante Assessment." *World Development* 38 (1):64-75. doi: https://doi.org/10.1016/j.worlddev.2009.03.014.

Mensah, Patience, and Andrew Tomkins. 2003. "Household-level technologies to improve the availability and preparation of adequate and safe complementary foods." *Food & Nutrition Bulletin* 24 (1):104-125.

Mitra, Surajit. 2012. "Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A malnutrition through a food-based approach." *J. Nutr. Food Sci* 2 (8):160. doi: 10.4172/2155-9600.1000160.

Mulokozi, Generose, Laurent Mselle, Joseph Mugyabuso, and Charlotte Johnson-Welch. 2001. "Reducing subclinical vitamin A deficiency through women's adoption of appropriate technologies in Tanzania." *Food & Nutrition Bulletin* 22 (4):400-407.

Murthy, P. V., K. V. Lakshmi, and M. S. Bamji. 1999. "Impact of home gardening and nutrition education in a district of rural India." *Bull World Health Organ* 77 (9):784.

Nair, Madhavan K., Little Flower Augustine, and Archana Konapur. 2015. "Food-Based Interventions to Modify Diet Quality and Diversity to Address Multiple Micronutrient Deficiency." *Frontiers in Public Health* 3:277. doi: 10.3389/fpubh.2015.00277.

Nana, C. P., I. D. Brouwer, N. M. Zagré, F. J. Kok, and A. S. Traoré. 2006. "Impact of promotion of mango and liver as sources of vitamin A for young children: a pilot study in Burkina Faso." *Public Health Nutrition* 9 (6):808-13. doi: http://dx.doi.org/10.1079/PHN2005911.

Nana, Constance P., Inge D. Brouwer, Zagr, Noel-Marie, Frans J. Kok, Traor, and Alfred S. 2005. "Community assessment of availability, consumption, and cultural acceptability of food sources of (pro)vitamin A: Toward the development of a dietary intervention among preschool children in rural Burkina Faso." *Food & Nutrition Bulletin* 26 (4):356-365.

Narasinga Rao, B. S. 2000. "Potential use of red palm oil in combating vitamin A deficiency in India." *Food & Nutrition Bulletin* 21 (2):202-211.

Narasinga Rao, B. S. 2001. "Dietary approaches to the prevention of vitamin A deficiency: Indian experience with red palm oil as a source of vitamin A." *Food & Nutrition Bulletin* 22 (4):395-399.

Ncube, T. N., T. Greiner, L. C. Malaba, and M. Gebre-Medhin. 2001. "Supplementing lactating women with pureed papaya and grated carrots improved vitamin A status in a placebo-controlled trial." *J Nutr* 131 (5):1497-502.

Ncube, T. N., L. Malaba, T. Greiner, and M. Gebre-Medhin. 2001. "Evidence of grave vitamin A deficiency among lactating women in the semi-arid rural area of Makhaza in Zimbabwe. A population-based study." *Eur J Clin Nutr* 55 (4):229-34.

Novotny, Janet A., Dawn J. Harrison, Robert Pawlosky, Vincent P. Flanagan, Earl H. Harrison, and Anne C. Kurilich. 2010. "β-Carotene Conversion to Vitamin A Decreases As the Dietary Dose Increases in Humans." *The Journal of Nutrition* 140 (5):915-918. doi: 10.3945/jn.109.116947.

Olney, D. K., A. Talukder, L. L. Iannotti, M. T. Ruel, and V. Quinn. 2009. "Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia." *Food and Nutrition Bulletin* 30 (4):355-369.

Omidvar, Nasrin, Mahmood Ghazi-Tabatabie, Gail G. Harrison, Shahriar Eghtesadi, Soltan-Ali Mahboob, and Mahdi Pourbakht. 2002. "Development and validation of a short food-frequency questionnaire for screening women of childbearing age for vitamin A status in northwestern Iran." *Food & Nutrition Bulletin* 23 (1):73-82.

Parlato, P. 1996. "Promoting vitamin A in rural Niger: strategies for adverse conditions." In *Strategies for Promoting Vitamin A Production, Consumption and Supplementation*, edited by R.E. Seidel, 7-25. Washington, DC: Academy for Educational Development

Persson, V., F. Ahmed, M. Gebre-Medhin, and T. Greiner. 2001. "Increase in serum beta-carotene following dark green leafy vegetable supplementation in Mebendazole-treated school children in Bangladesh." *Eur J Clin Nutr* 55 (1):1-9.

Peterson, S., V. Assey, B.C. Forsberg, T. Greiner, and et al. 1999. "Coverage and cost of iodized oil capsule distribution in Tanzania." *Health Policy and Planning* 14:390-399.
Phillips, M., T. Sanghvi, R. Suarez, J. McKigney, and J. Fiedler. 1996. "The costs and effectiveness of three vitamin A interventions in Guatemala." *Soc Sci Med* 42 (12):1661-8.
Radhika, M. S., P. Bhaskaram, N. Balakrishna, and B. A. Ramalakshmi. 2003. "Red palm oil supplementation: A feasible diet-based approach to improve the vitamin A status of pregnant women and their infants." *Food & Nutrition Bulletin* 24 (2):208-217.
Rahman, M. M., M. A. Islam, D. Mahalanabis, S. Chowdhury, and E. Biswas. 1994. "Impact of health-education on the feeding of green leafy vegetables at home to children of the urban-poor mothers of Bangladesh." *Public Health* 108 (3):211-218.
Rajasekaran, B. 1993. An Indigenous Duck–Fish Production System in South India. Impact on Food and Nutritional Security. Saginaw, MI: Consortium for International Earth Science Information Network.
Raymond, Jofrey, Neema Kassim, Jerman W. Rose, and Morris Agaba. 2017. "Context-specific food-based approach for ensuring nutrition security in developing countries: a review." *International Journal of Food Sciences and Nutrition*:1-7. doi: 10.1080/09637486.2017.1373751.
Reis, T. K., R.E. Seidel, S. Sudaryono, and A. Palmer. 1996. "The use of integrated media for promotion of vitamin A capsule consumption in central Java, Indonesia." In *Strategies for Promoting Vitamin A Production, Consumption and Supplementation: Four Case Studies*, edited by R.E. Seidel, 43-54. Washington, DC: Academy for Educational Development.
Ribaya-Mercado, Judy D, Florentino S Solon, Mercedes A Solon, Marilyn A Cabal-Barza, Christine S Perfecto, Guangwen Tang, Juan Antonio A Solon, Carla R Fjeld, and Robert M Russell. 2000. "Bioconversion of plant carotenoids to vitamin A in Filipino school-aged children varies inversely with vitamin A status." *The American Journal of Clinical Nutrition* 72 (2):455-465.
Rock, Cheryl L., Jennifer L. Lovalvo, Curt Emenhiser, Mack T. Ruffin, Shirley W. Flatt, and Steven J. Schwartz. 1998. "Bioavailability of β-Carotene Is Lower in Raw than in Processed Carrots and Spinach in Women1,2,3." *The Journal of Nutrition* 128 (5):913-916.
Roos, Nanna, Torben Leth, Jette Jakobsen, and Shakuntala Haraksingh Thilsted. 2002. "High vitamin A content in some small indigenous fish species in Bangladesh: perspectives for food-based strategies to reduce vitamin A deficiency." *International Journal of Food Sciences and Nutrition* 53 (5):425-437. doi: doi:10.1080/0963748021000044778.
Ruel, M. T. 2001. Can food-based strategies help reduce vitamin A and iron deficiencies? A review of recent evidence. Washington DC: International Food Policy Research Institute.
Semba, R. D., S. de Pee, K. Sun, A. A. Campbell, M. W. Bloem, and V. K. Raju. 2010. "Low intake of vitamin A-rich foods among children, aged 12-35 months, in India: association with malnutrition, anemia, and missed child survival interventions." *Nutrition* 26 (10):958-962. doi: 10.1016/j.nut.2009.08.010.
Shankar, Anita V., Joel Gittelsohn, Elizabeth K. Pradhan, Chandra Dhungel, and Keith P. West Jr. 1998. "Home gardening and access to animals in households with xerophthalmic children in rural Nepal." *Food & Nutrition Bulletin* 19 (1):34-41.
Siekmann, Jonathan H., Lindsay H. Allen, Nimrod O. Bwibo, Montague W. Demment, Suzanne P. Murphy, and Charlotte G. Neumann. 2003. "Kenyan School Children Have Multiple Micronutrient Deficiencies, but Increased Plasma Vitamin B-12 Is the Only Detectable Micronutrient Response to Meat or Milk Supplementation." *The Journal of Nutrition* 133 (11):3972S-3980S.
Sivan, YS, Y.A. Jayakumar, C. Arumughan, A. Sundaresan, A. Jayalekshmy, KP Suja, D.R.S. Kumar, SS Deepa, M. Damodaran, and CR Soman. 2002. "Impact of vitamin A supplementation through different dosages of red palm oil and retinol palmitate on preschool children." *Journal of tropical pediatrics* 48 (1):24-28.

Sloan, Nancy L, David Rosen, Trinidad de la Paz, Marylena Arita, Claver Temalilwa, and Noel W Solomons. 1997. "Identifying areas with vitamin A deficiency: the validity of a semiquantitative food frequency method." *American journal of public health* 87 (2):186-191.
Smitasiri, Suttilak. 2000. "Engaging communities in a sustainable dietary approach: A Thai perspective." *Food & Nutrition Bulletin* 21 (2):149-156.
Smitasiri, Suttilak, Kunanya Sa-ngobwarchar, Prapa Kongpunya, Charana Subsuwan, Orapin Banjong, Chuleeporn Chitchumroonechokchai, Wanpen Rusami-Sopaporn, Suriya Veeravong, and Sakorn Dhanamitta. 1999. "Sustaining behavioural change to enhance micronutrient status through community- and women-based interventions in north-east Thailand: Vitamin A." *Food & Nutrition Bulletin* 20 (2):243-251.
Soleri, D., D.A. Cleveland, and T.R. Frankenberger. 1991. Gardens and vitamin A: a review of recent literature. VITAL.
Solomons, N. W., and J. Bulux. 1997. "Identification and production of local carotene-rich foods to combat vitamin A malnutrition." *European Journal of Clinical Nutrition* 51:S39-S45.
Solomons, N.W., and M. Orozco. 2003. "Alleviation of vitamin A deficiency with palm fruit and its products." *Asia Pacific journal of clinical nutrition* 12 (3):373-384.
Solon, F., H. Briones, J.R. Fernandez, and L.B. Shafritz. 1996. "Moving to a long-term strategy: increasing vegetable gardening and consumption in the Philippines." In *Strategies for Promoting Vitamin A Production, Consumption and Supplementation: Four Case Studies*, edited by R.E. Seidel, 27–42. Washington, DC: Academy for Educational Development.
Tagwireyi, J., and T. Greiner. 1994. *Nutrition in Zimbabwe*. Washington DC: World Bank.
Takyi, E.E.K. 1999. "Children´ s Consumption of Dark Green, Leafy Vegetables with Added Fat Enhances Serum Retinol." *The Journal of nutrition* 129 (8):1549-1554.
Talsma, Elise F, Inge D Brouwer, Hans Verhoef, Gloria NK Mbera, Alice M Mwangi, Ayşe Y Demir, Busie Maziya-Dixon, Erick Boy, Michael B Zimmermann, and Alida Melse-Boonstra. 2016. "Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial." *The American Journal of Clinical Nutrition* 103 (1):258-267. doi: 10.3945/ajcn.114.100164.
Talukder, Aminuzzaman, Lynnda Kiess, Nasreen Huq, Saskia de Pee, Ian Darnton-Hill, and Martin W. Bloem. 2000. "Increasing the production and consumption of vitamin Arich fruits and vegetables: Lessons learned in taking the Bangladesh homestead gardening programme to a national scale." *Food & Nutrition Bulletin* 21 (2):165-172.
Tang, Guangwen. 2013. "Using plant foods rich in β-carotene to combat vitamin a deficiency." *Sight and Life* 27 (1):20-28.
Tang, Guangwen, Xiu-fang Gu, Shan-ming Hu, Qing-mei Xu, Jian Qin, Gregory G Dolnikowski, Carla R Fjeld, Xiang Gao, Robert M Russell, and Shi-an Yin. 1999. "Green and yellow vegetables can maintain body stores of vitamin A in Chinese children." *The American Journal of Clinical Nutrition* 70 (6):1069-1076.
Thurnham, D. I. 2007. "Bioequivalence of beta-carotene and retinol." *Journal of the Science of Food and Agriculture* 87 (1):13-39. doi: 10.1002/jsfa.2647.
Torheim, L. E., E. L. Ferguson, K. Penrose, and M. Arimond. 2010. "Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients." *J Nutr* 140 (11):2051s-8s. doi: 10.3945/jn.110.123463.
Torronen, R., M. Lehmusaho, S. Hakkinen, O. Hanninen, and H. Mykkanen. 1996. "Serum beta-carotene response to supplementation with raw carrots, carrot juice or purified beta-carotene in healthy non-smoking women." *Nutrition Research* 16 (4):565-575. doi: 10.1016/0271-5317(96)00035-8.
Turner, Tami, Betty J Burri, Kazi M Jamil, and Maleka Jamil. 2013. "The effects of daily consumption of β-cryptoxanthin–rich tangerines and β-carotene–rich sweet potatoes on vitamin A and carotenoid concentrations in plasma and breast milk of Bangladeshi women with low vitamin A status in a randomized controlled trial." *The American Journal of Clinical Nutrition* 98 (5):1200-1208. doi: 10.3945/ajcn.113.058180.
Underwood, B.A., and S. Smitasiri. 1999. "Micronutrient malnutrition: Policies and programs for control and their implications." *Annual review of nutrition* 19 (1):303-324.

UNICEF. 2013. IMPROVING CHILD NUTRITION, The achievable imperative for global progress. New York: UNICEF.
van het Hof, Karin H., Clive E. West, Jan A. Weststrate, and Joseph G.A.J. Hautvast. 2000. "Dietary Factors That Affect the Bioavailability of Carotenoids." *The Journal of Nutrition* 130 (3):503-506.
van Jaarsveld, P. J., De Wet Marais, E. Harmse, P. Nestel, and D. B. Rodriguez-Amaya. 2006. "Retention of β-carotene in boiled, mashed orange-fleshed sweet potato." *Journal of Food Composition and Analysis* 19 (4):321-329. doi: http://dx.doi.org/10.1016/j.jfca.2004.10.007.
van Jaarsveld, Paul J, Mieke Faber, Sherry A Tanumihardjo, Penelope Nestel, Carl J Lombard, and Ambrose J Spinnler Benadé. 2005. "β-Carotene–rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test." *The American Journal of Clinical Nutrition* 81 (5):1080-1087.
van Stuijvenberg, M. E., Benad, and A. J. S. 2000. "South African experience with the use of red palm oil to improve the vitamin A status of primary schoolchildren." *Food & Nutrition Bulletin* 21 (2):212-214.
Vijayaraghavan, K. 2002. "Control of micronutrient deficiencies in India: Obstacles and strategies." *Nutrition Reviews* 60 (5):S73-S76.
Vijayaraghavan, K., MU Nayak, MS Bamji, GNV Ramana, and V. Reddy. 1997. "Home gardening for combating vitamin A deficiency in rural India." *FOOD AND NUTRITION BULLETIN-UNITED NATIONS UNIVERSITY-* 18:337-343.
Von Braun, J., J. McComb, B.K. Fred-Mensah, and R. Pandya-Lorch. 1993. Urban food insecurity and malnutrition in developing countries: trends, policies and research implications. Washington DC: International Food Policy Research Institute.
Vuong, Le T, Stephen R Dueker, and Suzanne P Murphy. 2002. "Plasma β-carotene and retinol concentrations of children increase after a 30-d supplementation with the fruit Momordica cochinchinensis (gac)." *The American Journal of Clinical Nutrition* 75 (5):872-879.
Wasantwisut, Emorn, Uraiporn Chittchang, and Sangsom Sinawat. 2000. "Moving a health system from a medical towards a dietary approach in Thailand." *Food & Nutrition Bulletin* 21 (2):157-160.
Worldview International Foundation. 1995. Comprehensive nutrition and blindness prevention programme. Dhaka, Bangladesh: Worldview International Foundation.
Yusuf, H. K. M., and M. N. Islam. 1994. "Improvement of nightblindness situation in children through simple nutrition education intervention with the parents." *Ecology of Food and Nutrition* 31 (3-4):247-256.
Zagré, NM, F Delpeuch, P Traissac, and H Delisle. 2003. "Red palm oil as a source of vitamin A for mothers and children: impact of a pilot project in Burkina Faso." *Public Health Nutrition* 6 (08):733-742. doi: doi:10.1079/PHN2003502.