CHALLENGE THEME PAPER 3: NUTRITIONAL IMPACT WITH ORANGE-FLESHED SWEETPOTATO (OFSP)

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Overall Challenge: How can we get provitamin A rich orange-fleshed sweetpotato (OFSP) into the diet of the most vulnerable groups?

BACKGROUND

In contrast to Asia, malnutrition among young children is on the rise in Sub-Saharan Africa. A key millennium development goal (MDG) called for the reduction of underweight prevalence by 50% by the year 2015. Overall, in Africa, prevalence is expected to increase from 24% in 1990 to 27% in 2015. High rates of HIV/AIDS prevalence exacerbate malnutrition. Hence in East Africa, where the HIV/AIDS effect is strong, underweight prevalence is predicted to be 25% higher in 2015 than in1990 (The World Bank, 2006).

Vitamin A is an essential micronutrient for human health. Vitamin A deficiency (VAD) is widespread among young children in the developing world; globally, 127 million children under six years of age are estimated to be affected (West, 2002). Sub-Saharan Africa (SSA) and India have the highest estimated prevalence rates of sub-clinical vitamin A deficiency (Figure 3.1). VAD can limit growth, weaken immunity, cause xeropthalmia leading to blindness, and increase mortality (Sommer and West, 1996).

There are two types of vitamin A available in foods: preformed retinol (vitamin A itself) typically found in animal foods such as eggs, liver, and milk; and provitamin A carotenoids found in plant foods such as dark green leafy vegetables, yellow and orange vegetables and fruits, and orange-fleshed sweetpotato (McLaren and Frigg, 2001). Β-carotene is the major provitamin A carotenoid, and the dominant carotenoid in orange-fleshed sweetpotato.

Poor households typically cannot afford to consume the highly bioavailable animal foods on a regular basis. High rates of deficiency in the major micronutrients (vitamin A, iron [Fe], and zinc [Zn]) are common among poor populations that consume plant-based diets (Hess *et al.*, 2005). Many plant sources of vitamin A are seasonal, and after provitamin A carotenoids are absorbed into the body, they must be converted into retinol for the body to be able to make use of them. Rates of conversion vary among carotenoid containing plant foods (up to five fold) and also depend on what else is consumed at the same time (for example, fat increases absorption) and the health status of the individual (e.g. more deficient individuals absorb and/or convert at higher rates than replete individuals). Heat processing may also increase conversion rates compared to the raw product, depending on the plant matrix (Hess *et al*., 2005). Current guidelines recommend that provitamin A activity be expressed in Retinol Activity Equivalents (RAE). The RAE definition is based on the assumption that 16.7% of the ingested beta-carotene is absorbed and 50% is converted to retinol. This results in an average conversion factor of 12 units of beta-carotene to form 1 RAE. Many dark green leafy vegetables are probably less bioavailable than this, while palm oil is far superior (2:1 conversion factor). In contrast, the conversion factor for preformed retinol from animal sources is 1:1 and for other provitamin A carotenoids 24:1 (Institute of Medicine, 2001).

During the past five years, further evidence has been obtained regarding the potential impact of OFSP on young child vitamin A status. A South African study demonstrated that OFSP is bioavailable and efficacious in improving vitamin A status in children (Jaarsveld *et al*,. 2005) and significant improvements in vitamin A intake and serum retinol concentrations (a proxy for vitamin A status) were obtained from an action-research study of an OFSP-based integrated agriculture-nutrition-market intervention in a very resource poor setting in Central Mozambique (Low *et al*., 2007b). The latter study emphasized the importance of having all three components (agriculture, nutrition and market interventions) to ensure improvement in young child vitamin A intakes and sustained adoption of the new material. A third study (Haskell *et al.,* 2004) using the isotopic tracer deuterated retinol to estimate total vitamin A stores in 14 Bangladeshi men determined a conversion factor of 13:1 for orange-fleshed sweetpotato when it was cooked pureed with a small amount of oil.

Orange-fleshed sweetpotato as a staple food has an advantage over most vegetables in that it can supply significant amounts of vitamin A *and* energy simultaneously -- thus helping to address both VAD and undernutrition. OFSP is an example of a *biofortified* crop in which the micronutrient status of staple foods is enhanced through plant breeding to the point where impact on micronutrient status can be achieved (Bouis, 2002). Since the poorest households typically obtained over 60% of their energy needs from food staples, this strategy is particularly suited to poor rural households that cannot access purchased fortified food products but could grow OFSP.

The intensity of the orange color reflects the amount of beta-carotene present in the sweetpotato. In most of SSA, white-fleshed varieties dominate and contain no beta-carotene. On a fresh weight basis (fwb), light orange varieties contain at least 250 RAE/100 gms (30 μg/g), medium-intensity varieties at least 458 RAE/100 gms (55 μg/g) and dark-orange -varieties at least 833 RAE/100 gms (100 μg/g). To put things into perspective, the recommended daily intake for healthy two and five year old children is 400 RAE and 500 RAE, respectively (Institute of Medicine, 2001). Depending upon the color intensity of the OFSP variety used and taking losses during cooking into account (approximately 20% through boiling), 1/4 to 1 cup of boiled and mashed sweetpotato meets the intake requirements of a young child.

Sweetpotato leaves are also consumed in many countries in SSA, with the notable exceptions of Kenya and Uganda where they are principally considered to be animal feed. The leaves also contain significant amounts of beta-carotene, but bioavailability is certain to be much lower than for the OFSP roots and to our knowledge, no formal study has been done to determine the conversion rate of beta-carotene from sweetpotato leaves into retinol.

Because of the urgent need to address widespread VAD in SSA, the development and use of beta-carotene-rich OFSP roots deserves special consideration in any sweetpotato initiative. Compelling evidence is available of the potential contribution of OFSP to improved nutrition. To evaluate potential health and economic impact, economists estimate the number of vitamin A deficiency (VAD)-related Disability-Adjusted Life Years (DALYs) that could potentially be saved through the use of biofortified sweetpotato. Results indicate that just by replacing white-fleshed with orange-fleshed varieties the VAD burden could be reduced by 15 to 22% in 17 SSA countries where sweetpotato is widely grown (Stein *et al.*, 2005; Fuglie and Yanggen *in press*). *Ex-ante* analysis determined that if OFSPs were adopted by one-in-six Ugandan households within 10 years of becoming available, the effort would achieve an estimated internal rate of return between 16 and 30 percent and yield a net present value between $23 million and $67 million (Fuglie and Yanggen *in press*).

The focus of this theme is on the narrower nutritional objectives associated with OFSP for humans. OFSP varieties with adequate agronomic performance are already available in several SSA countries; therefore it is the first biofortified crop in use at farmer level and serves as a model for the adoption of biofortified crop with a visible trait. Further breeding work is needed to improve agronomic and organoleptic qualities to ensure sustained adoption and is discussed in Challenge Theme Paper 1 on Breeding. OFSP, either in fresh or processed form, can be branded as a health improving product. When marketed to urban consumers, there are additional income benefits for rural producers that could induce a potentially complementary impact on nutrition through increased spending on other health enhancing services and products. The marketing aspects of OFSP promotion are addressed in Challenge Theme paper 4 on Value chain.

Challenge 3.1. Increase the bioavailability of micronutrients in OFSP and retention during processing and storage

Orange-fleshed sweetpotato roots and leaves contain a diverse array of vitamins and minerals with potential nutritional benefits. The ultimate benefit depends on the total amount of micronutrients ingested and whether the micronutrients are retained during processing and storage and are absorbed and utilized by the body after being consumed.

Nutrient content of roots and leaves

OFSP roots are a rich source of provitamin A and can meet easily the intake needs of young children in their commonly served form, boiled or steamed, as noted above. True retention (TR) of beta-carotene varies from 70-92%, depending on cooking time (longer cooking periods lowering TR) and whether the pot was covered with a lid (covering increases TR) (Jaarsveld *et al.* 2006). Dominant varieties of maize and cassava, in comparison, have no vitamin A (Table 3.1), although biofortification efforts are underway to improve beta-carotene contents in these crops. Although sweetpotato leaves contain ample amounts of beta-carotene, the amount of vitamin A available per 100 grams is estimated to be much lower (51 ug/100 gms) due to its presumed lower bioavailability, as no efficacy study has been done using sweetpotato leaves. Sweetpotato roots also are a good source of vitamin C and have moderate amounts of several B vitamins and vitamin E (Table 3.1). Protein levels in sweetpotato and cassava leaves are higher than in their respective roots, but the amount of leaves consumed by humans limits their total contribution.

Sweetpotato leaves are widely consumed in several SSA countries, yet varietal specific information on nutritional benefit is limited in SSA compared to Asia, as is data on the average amount consumed and the seasonality of consumption. The promotion of their consumption exists in a few initiatives, mostly through home or school gardens. Part of the difficulty in comparing sweetpotato leaves from different varieties for human consumption is that young leaves are typically harvested piecemeal during the growing season. Hence, by the time roots are evaluated at the end of the growing season, the leaves from some varieties lack the desired palatability as fiber has accumulated. Hence, incorporation of regular assessment of organoleptic qualities of sweetpotato leaves has logistic and cost implications. Specific varieties for use as a vegetable only do exist, but these are only being evaluated on a small-scale in Kenya and Tanzania.

Table 3.1. Nutrient composition of orange-fleshed sweetpotato, cassava and maize.

Nutrient	Units/ 100 gms	Orange-fleshed Sweetpotato		Cassava		Maize
		Raw Roots	Leaves	Raw roots	Leaves	White flour
Vitamin A	Ug	300-1300	51-230	1	115	0
Iron	Mg	0.32-0.88	1.01	0.27	7.6	2.4
Zinc	Mg	0.18-0.57	0.29	0.34	0.40	1.70
Thiamin (B1)	Mg	0.08	0.16	0.09	Na	0.25
Riboflavin (B2)	Mg	0.06	0.34	0.05	Na	0.08
Niacin (B3)	Mg	0.56	1.13	0.85	2.40	1.90
Vitamin B6	Mg	0.21	0.19	0.09	Na	0.37
Vitamin E	Mg	0.26	na	0.19	Na	0.42
Vitamin C	Mg	22.7	11.0	20.6	310	0
Protein	G	1.6	4.0	1.4	7.0	6.9
Fiber	Mg	3.0	2.0	1.8	4.0	9.6
Phytate	Mg	10	42	54	42	792

As noted in the Theme paper on breeding, there is a positive correlation in the sweetpotato germplasm between beta-carotene, iron, and zinc. If included as a selection criterion in breeding programs, average levels of iron and zinc in OFSP could be expected to double within the next five years. The range of iron and zinc values found to date in OFSP germplasm is provided in Table 3.1. Iron and zinc deficiency are the other two widespread micronutrient deficiencies in the world, with their deficiencies associated with increased susceptibility to infection, impaired growth, anorexia, and impaired cognitive function. Iron deficient anemia is estimated to affect over 1 billion people worldwide (Hess *et al*., 2005). Clearly, if the three micronutrients could be enhanced simultaneously that would be highly desirable

However, a main constraint inhibiting the contribution of iron and zinc contributing to improved nutritional status is the low rates of absorption associated with plant sources of iron and zinc. Similar to the situation found in vitamin A, flesh foods are rich sources of bioavailable heme iron and zinc, whereas many plant sources contain high levels of phytate and in some, polyphenols, which inhibit the absorption of iron and zinc —even when they are present in relatively large amounts. Levels of phytates are particularly high in unrefined cereals, nuts, and legumes. Phytate levels are higher in sweetpotato leaves than roots. One study from the Philippines found that only 5% of the iron from sweetpotato leaves was absorbed (Ortaliza *et al.,* 1974). The negative effect of phytates on zinc uptake can be mitigated by increasing amount of dietary proteins consumed (WHO, 2002). The phytate level in sweetpotato roots, however, is quite low compared to that found in maize (Table 3.1). Moreover, sweetpotato has considerable amounts of vitamin C, which enhances non-heme iron absorption (Nestel and Nalubola, 2003). However, the effect of phytate comes from the amount in the entire meal. Hence, if sweetpotato is consumed along with maize, for instance, the inhibitory effect on absorption would still be there. As sweetpotato is consumed in some areas as a stand-alone breakfast food, in these instances phytate inhibition would be minimal.

In addition, many studies have demonstrated a positive effect that vitamin A supplements or vitamin A fortified foods have had on hemoglobin concentrations in children and pregnant and lactating women (Semba and Bloem, 2002). Evidence of interactive effects between vitamin A and zinc is much less clear (Hess *et al.*, 2005). Since OFSP is naturally biofortified with provitamin A, one might expect that the effects on iron status through increased OFSP consumption might be positive.

Requirements for several nutrients in terms of averages for assessing populations (EARs) and recommend intakes for individuals (that have an additional safety margin built in to assure adequate nutrient status) are provided in Table 3.2 for two key target groups: children 1-3 years of age and non-pregnant women 19-30 years of age as a reference. The target level set by HarvestPlus to consider a staple food crop biofortified in a specific nutrient is 40% of the daily EAR requirement for a non-pregnant adult woman. With this definition and assuming that 200 grams of sweetpotato is consumed, 100 grams of sweetpotato would have to provide 1.6 mg fwb of zinc and 1.7 mg fwb of iron. While the levels of iron and zinc content achievable via conventional breeding will not be able to attain "biofortified" status for adult women, it is possible that a significant contribution towards improved intake of young children 1-3 years of age could be made. Given their lower requirements, only 0.56 mg and 0.63 mg of zinc and iron in sweetpotato roots would meet 40% of their requirements, if the bioavailability of these micronutrients is confirmed.

Quality traits as a function of the environment

Like many other sweetpotato traits, the quality traits have been found to be influenced by the environments. For example, the average dry matter content varies widely depending on cultivars, environments and cultivation practices, from 13.8 to 48.3% (Bradbury and Holloway, 1988). Existing study findings on stability of β-carotene contradict each other. While some studies (Manrique and Hermann, 2000; Gruneberg *et al.*, 2005) found extremely low environment interaction effects, Kosambo *et al.* (1998) and Ndirigue (2005) report significant effects on levels of β-carotene. On the other hand Manrique and Hermann (2000) observed increased concentrations of ß-carotene at high altitudes among the studied clones. Similar observations in just one variety have been made by Dr. Mulokozi (personal communication). Thus ß-carotene levels of popular sweetpotato varieties in the region are not clearly known, due to large estimate variations in different environments. Knowledge on the influence of environment on ß-carotene is of great importance in guiding recommendations by the nutritionists on intakes to meet daily requirements of vitamin A by sweetpotato as well as in evaluating the stability of β-carotene in sweetpotato cultivars or breeding clones under different environmental conditions. Lack of stability in beta-carotene content would complicate commercialized processed product development as processors would have to deal with an inconsistent product.

Table 3.2. Estimated average requirements (EARs) for group level analysis and individual level requirements of essential nutrients.

Nutrient		**Estimated Average Requirements (EAR) for Groups**		**Recommended Intakes for Individuals**	
	Units/ day	Child 1-3 years	Female 19-30 years	Child 1-3 years	Female 19-30 years
Vitamin A	ug	210	500	300	700
Iron	mg	3	8.1	7	18
Zinc	mg	2.5	6.8	3	8
Thiamin (B1)	mg	0.4	0.9	0.5	1.1
Riboflavin (B2)	mg	0.4	0.9	0.5	1.1
Niacin (B3)	mg	5	11	6	14
Vitamin B6	mg	0.4	1.1	0.5	1.4
Vitamin E	mg	5	12	6	15
Vitamin C	mg	13	60	15	75
Protein	g	11	38	13	46

Source: Institute of Medicine (2001), except for zinc. Zinc figures from International Zinc Nutrition Consultation Group

The influence of the varied time of harvesting on the ß-carotene levels in sweetpotato is also not fully understood. Most farming communities harvest sweetpotato piecemeal allowing households to get food early before total crop maturity, and also minimize food wastage through ground storage of an otherwise perishable crop. However, the nutritional content of the root is reported to change with time during the crop growth (Woolfe, 1992). For example, the level starch accumulates with time. Also the protein root content levels are reported to vary with date to harvest. A declining trend was observed for leaf ß-carotene content in sweetpotato cultivars with increasing time of harvest. Kosambo *et al.* (1998) found significant effect of storage root age on carotenoid content. Twelve weeks after planting, the yield and the amount of pro-vitamin A present in the roots evaluated were high enough to provide adequate dietary pro-vitamin A and means there would be some nutritional benefit if piecemeal harvesting began at that time. More recent studies by the Tanzanian Food and Nutrition Center (TFNC) also found significant effect of maturity on β-carotene content of sweetpotato roots (Personal communication, Generose Mulokozi). Varieties harvested at 7-8 months had significantly higher β-carotene content than varieties harvested at 4-5 months. Apart from appropriate date of harvesting recommendations for root yields, there is need to determine the appropriate date of harvesting to maximize the availability of pro-vitamin A carotenoids in sweetpotato roots.

In addressing micronutrient deficiencies the potential for exploiting soil-crop nutrition-human nutrition interactions should not be overlooked. For example, a plant that is zinc deficient will suffer from reduced yields. Moreover, the low concentration of zinc in its tissue reduces its nutritional value as a human food. Zinc fertilizers do exist, and the possibility of enhancing the micronutrient content of the human diet through improved crop health is unexploited territory in SSA (Alloway 2004). It is also possible to consider the use of foliar sprays. Applications of foliar sprays containing minerals were found to enhance the concentrations of some minerals and trace elements in the same variety in the same field (Paterson and Speights 1971). The Zn containing spray significantly increased the leaf Zn content, but when Fe was applied, the calcium and boron content was lowered.

Retention of Beta-carotene during processing

Wheatley and Loechl (2008) review the major studies undertaken during the past two decades concerning OFSP products and retention of beta-carotene during processing and storage (pp. 12-23). During this time, there has been considerable improvement and greater standardization of procedures used to assess beta-carotene content (Rodriguez-Amaya and Kimura, 2004). Research in this area is constrained by the high cost of doing beta-carotene assessment using HPLC and other nutrient analysis. The review concludes that:

1) OFSP varieties have beta-carotene contents high enough to contribute significantly (after cooking/processing) to the daily recommended intake of young children.
2) Medium-to-dark orange fleshed varieties should be preferred for processing over lighter orange-fleshed materials (having less than 50 μg beta-carotene per gram fresh root weight).
3) Some food products containing OFSP such as bread, mandazi, and chapati are of good quality and acceptable to consumers, including children.
4) Bakers/processors can reap some advantages from the use of OFSP raw materials, but in some areas their commercial uptake may be hampered by cost disadvantages and supply problems.

5) Storage of dried roots should be for less than 4 months, when dramatic carotenoid losses were shown; losses may be lower with fresh roots when stored for short periods.

More research is clearly required to:

1) Understand losses in beta-carotene after different time periods of storage (1 week, 1 month, 2 months).
2) Develop and test low-cost methods on how to reduce degradation of beta-carotene during storage of fresh and dried roots, particularly at the household level.
3) Develop and implement standardized protocols for the collection of relevant data on the profitability and beta-carotene content of products.

Future areas of work for consideration:

1) Understanding the bioavailability of iron and zinc in sweetpotato roots with high beta-carotene contents and improved iron and zinc contents.
2) Understanding the bioavailability of vitamin A in sweetpotato leaves.
3) Understanding the influence of maturity and other varietal characteristics on the rates of micronutrient accumulation in roots.
4) Understanding the relationship between soil fertility and beta-carotene and other relevant micronutrients.
5) Understanding the potential for micronutrient enhancement in sweetpotato roots through the use of micronutrient enhanced fertilizers.
6) Research on methods for improving micronutrient retention during storage and processing and the influence of varietal type on retention.
7) Development of lower cost methods for assessing micronutrient content in OFSP-based processed products.

Challenge 3.2. Maximizing the nutritional impact of OFSP

Vitamin A deficiency (VAD) is not just the result of inadequate vitamin A intake. Maximizing the nutritional impact of an OFSP is complex and requires choices to be made regarding target groups and the design and intensity of the non-agricultural components of the intervention.

Undernutrition is not just the result of inadequate food intake, but is also caused by: the quality of the food being consumed, poor access to health services, poor sanitation, and in the case of young children, inappropriate feeding and care practices. In the same vein, VAD can have multiple causes: inadequate vitamin A intake because the sources of vitamin A are lacking in the diet or the source of vitamin A is not adequately bioavailable, inadequate absorption of vitamin A because the lining of the intestine may be damaged by parasites or diarrhea, or increased use of vitamin as the body fights off diseases such as measles and malaria.

Children under five years of age and pregnant and lactating women are at greatest risk of VAD. In recent years, attention has particularly focused on the young child due to studies in the 1980's that proved that large-scale vitamin A supplementation led to significant (on average 23%) child mortality reduction (McLaren and Frigg, 2001). Moreover, a recent reassessment of the nutrition situation concluded that the best opportunity for addressing malnutrition is the period prior to conception until two years of age (World Bank, 2006). However, there are many reasons that other target groups might be considered for an OFSP-based intervention. These are summarized in Table 3.3 along with consideration of what might be the potential challenges working with a given target group. For example, investing in reaching school children, the future parents of the world, may be an effective means for reaching large numbers of households through a centralized location *if* children prove to be effective transmitters of technologies from school to household. Moreover, influencing preferences and changing behaviors regarding diet and heath practices is complex and young children are under the strong influence of their parents and other adult caretakers (Nicklas *et al.,* 2001). In addition, experience to date indicates that adult preferences in varietal selection (taste in particular) often differ from young child preferences, but adults determine what varieties are grown and how much are grown.

The three most common strategies for combating VAD are distribution of vitamin A supplements, food fortification, and food-based approaches that aim to increase access to and intake of vitamin A-rich foods. Clearly, an OFSP-based intervention falls in the latter category. Food-based approaches can be seen as complementary to the other strategies and particularly suited for rural areas where access to fortified foods is limited by availability or purchasing power. A food based strategy has the advantage of bringing in more nutrients, both macro- and micro-, than just vitamin A, and may be more sustainable.

Table 3.3. Description of reasons for potentially targeting different groups with ofsp-based interventions, alternative sources of vitamin a to which the target group may have access and the challenges of working with that group

Target Group	**Reason for Targeting**	**Alternative Sources of Vitamin A**	**Challenges of Working with this Group**
Children 6-12 months	High risk of VAD and mortality	Age group most likely to still be breast fed and to receive vitamin A capsules (attend for immunizations)	Requires working with mothers on special dietary requirements and care practices for this age group
Children 12-24 months	Very high risk of VAD and mortality, especially among children no longer breastfeeding	May have access to vitamin A capsules in many countries; some have breast milk	Requires working with caretakers on special dietary requirements and care practices for this age group
Children 25-59 months	High risk of VAD and mortality	May have access to vitamin A capsules in many countries	Child typically eating what family eats and shares with others
School children	Opportunity to influence lifetime food preferences; Mothers and fathers of the future; Central location for demonstration –lowering operational costs; ? Potential for knowledge transmission to other household members; ? Potential for sustained integration into curriculum (large-scale impact)	May have access to school feeding programs that could included fortified foods	Bureaucratic resistance; requires teacher and/or parental community involvement; maintenance of gardens/fields when school not is session; age-specific training approach & materials
Adolescents	Higher vitamin A during adolescent growth; Opportunity to educate and improve status, esp. among girls, prior to parenthood	Only through growing or purchasing vitamin A rich foods	Reaching school drop-outs; age-specific training approach & materials; requires parental cooperation/consent
Pregnant Women	Greater vitamin A requirements than normal; Concentration of vitamin A in breast milk depends on woman's vitamin A status	In some countries, may have access to vitamin A capsule immediately after birth of child	Identifying candidate women at early stage & special dietary needs
Fathers	Often determine or influence what is grown and what is sold (varies by culture/household) & care practices	Through growing or purchasing vitamin A rich foods	May perceive nutrition as woman's area
Elders	Often influence household dietary and young child care practices	Through growing or purchasing vitamin A rich foods	Difficult changing beliefs; Physical ability to participate; Age-specific approach for training activities and materials
Food Insecure Rural Households	Have household members at high risk of VAD and undernutrition; Diet diversification enhances health of all members	Through growing or purchasing vitamin A rich foods; young children may have access to vitamin A supplements	Vine maintenance in drought-prone areas; Requires cost-effective approach for assuring adoption and appropriate use; Competition with other crops/activities
Urban slum dwellers	Have household members at high risk of VAD and undernutrition;	Through growing or purchasing vitamin A rich foods; may have greater access to fortified foods than rural dwellers; young children may have access to supplements	Land/water for cultivation may be limiting; Cooperation and/or adequate time availability from potential beneficiaries; support from municipalities
Displaced populations	Often suffering from multiple nutritional problems, including VAD; Food insecure, hence anxious for productive technologies	Food aid may be fortified with micronutrients	Multiplication rate of sweetpotato requires lead time for large-scale response; Limited contact time per beneficiary; High rates of dis-adoption likely; hard to monitor uptake if mobile population
HIV/AIDs affected persons	High risk of VAD and mortality; Require easy to manage technologies; Often food and income insecure	May have access to micronutrient supplements or fortified food supplements	Identifying candidate beneficiaries; Capacity of individuals to do physical labor—often requires working at community level; complex as links to health service provision essential

The design of integrated interventions can be complex as it requires a multi-disciplinary approach. The example of the Towards Sustainable Nutrition Improvement project (TSNI) can serve as a case in point (Low *et al.,* 2007a). In this model, OFSP is not a "magic bullet" but an easily exploitable resource to enable resource-poor households to provide adequate nutrition to their most vulnerable household members. OFSP provides an entry point for change agents to empower poor caregivers to change behaviors concerning dietary practices. There are three components: 1) *Agriculture*: consisting of the introduction of a new source of vitamin A and energy, biofortified OFSP; 2) Demand Creation and Empowerment through improved knowledge of *Nutrition*: At the village level, principal caregivers, both women and men, are encouraged and enabled to improve infant and young child feeding practices, hygiene practices, and diversify the household diet. Demand creation efforts focus on building awareness among the broader community to create: a) demand for the new OFSP cultivars and its derivatives, b) demand for other vitamin A-rich foods, and c) a supportive environment to accelerate behavior change at the household level; and 3) *Market Development*: This component aims to link farmers to traders and to inform consumers about where they can purchase OFSP. Farmers able to commercialize their crop are more likely to permanently adopt the crop and expand the area under production. This action research study demonstrated significant increases in vitamin A intake and a 15% reduction in prevalence of low serum retinol (a proxy for vitamin A status) in young children in spite of the poor health environment (Low *et al.*, 2007b). A follow-up study, the Reaching End Users, is currently investigating whether a variant of this model, in which an explicit attempt was made to lower the cost of the intervention, can be cost-effectively scaled-out. The design is explained in greater detail in Challenge 3.4.

The TSNI approach was an integrated package and further study is needed as to which components of this package are essential for adoption and impact on young child vitamin A intake. Many small-scale interventions are currently underway in SSA that utilize OFSP (Field team visits, May-June 2008), but most are just integrating OFSP into larger agricultural initiatives with limited focus on understanding which components are critical to uptake and proper utilization. One question is whether OFSP will "passively" end up in the young child diet and have a significant impact on the group most at risk of VAD when interventions are generally targeted at rural households without a specific intervention to change young child feeding and care practices.

There are also questions as to whether linking an agricultural-nutrition intervention more explicitly to a health intervention would substantially increase impact on VAD status. A clinical trial in Indonesia (Jalal *et al.*, 1998) utilizing sweetpotato-based weaning foods demonstrated that the greatest rise in serum retinol occurred when meals contained added beta-carotene sources and added fat and the children were de-wormed. The potential of this type of OFSP-based agriculture-nutrition-health intervention has not yet been tested at the community level in SSA.

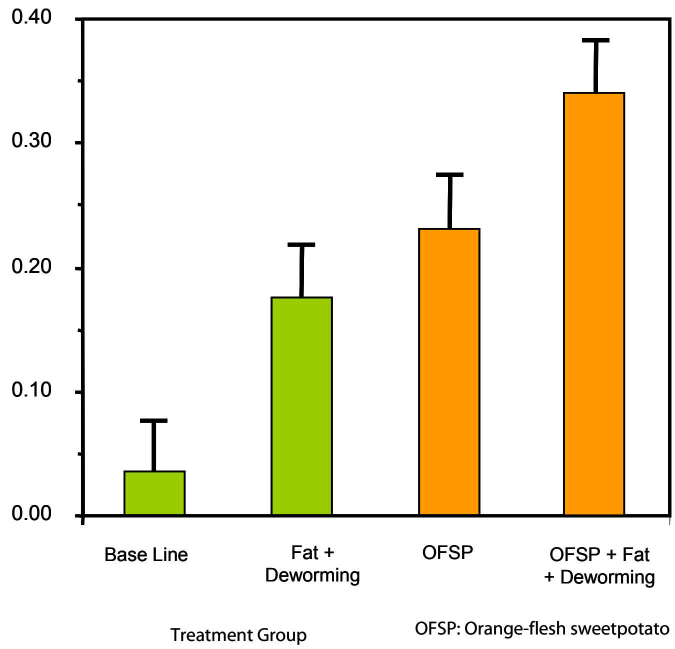

Figure 3.1
Change in serum retinol (vitamin A status indicator) (Jalal *et al.*,1998).

Clearly, reaching the most at risk group of VAD (children under 2 years of age) requires addressing a broad range of child feeding and care practices and is a more complex intervention than just aiming at rural households. Assuring behavior change regarding OFSP use in the household is more complex than just creating awareness that OFSP is good for health. Increasing vitamin A intake is only part of the solution; health interventions are essential to improve the absorption of vitamin A in the body. The challenge is to find which entry points in reaching vulnerable households and specific target groups have the best chance for sustained adoption and widespread impact in short, medium, and longer-term interventions.

Future areas of work for consideration:

1) Investigating the use of OFSP linked to a health intervention that will decrease vitamin A loss (for example, de-worming or targeting pregnant women receiving pre-natal care) and enhance the impact of an integrated OFSP-based intervention;
2) Understanding how to better evaluate young child and school-age children preferences compared to adult preferences;
3) Understanding whether OFSP reaches the group most at risk of vitamin A deficiency (children under five) when targeting households for food security or commercialization interventions;
4) Understanding whether school children are effective entry points for knowledge and technology transmission to other household members.

Challenge 3.3. Maximize the role of OFSP in mitigating the situation of persons living with HIV/AIDS (PLWH)

The high prevalence of HIV/AIDS, particularly in Eastern and Southern Africa, exacerbates the malnutrition situation and could affect the design and outcome of any potential OFSP intervention. Adequate nutrition is essential for the success of expensive anti-retroviral treatment regimes.

Current knowledge

SSA continues to be the region most affected by the deadly HIV pandemic: 68% of adults and 90% of children infected with HIV are in SSA. In 2007, a staggering 22.7 millions adults and children were living with AIDS with 1.6 million deaths attributed to the disease that year in SSA. Unlike other continents, the majority (61%) of those living with AIDS in SSA are women. The highest prevalence rates in SSA are in Southern Africa (35% of all cases in SSA and 32% of new infections), followed by Eastern Africa, where data indicate that prevalence is stabilizing or declining (UNAIDS and The World Health Organization, 2007). HIV/AIDS and malnutrition have long been know to co-exist, often resulting in the "slimming disease" so characteristic of early AIDS patients. A complex set of underlying primary malnutrition, primary effects of AIDS virus infection, secondary effects of AIDS and finally AIDS complications can all lead to a vicious cycle, as illustrated in the figure and updated in recent reviews for the HIV stage (Faintuch *et al.*, 2006) and highly active anti-retroviral therapy (HAART) stages (Drain *et al.*, 2007). Decreased appetite and taste for food are among the important factors not indicated in the figure (Berti, 2008). Several studies have shown that malnutrition is a common problem among people undergoing HAART in resource-poor settings, and that wasting is one of the best predictors of risk of mortality (Paton *et al.*, 2006; Zachariah *et al.*, 2006)

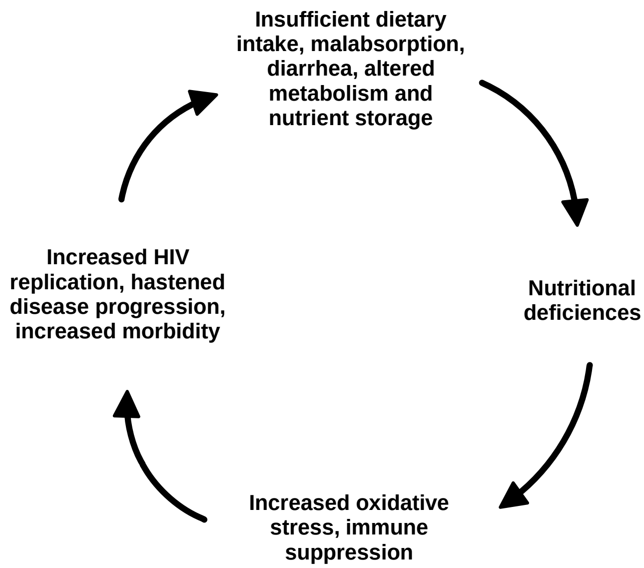

Figure 3.2
Vicious cycle of micronutrient deficiencies and human immunodeficiency virus (HIV) pathogenesis.

Source: Semba and Tang, 1999.

Of particular relevance for OFSP is that energy requirements increase with HIV infection (approximately 10%) and further with active AIDS (20-30%) (Berti, 2008), to which OFSP could potentially respond, and that HIV infection appears to impair absorption of Vitamin A (Kelly *et al.*, 2001), requiring greater intakes of Vitamin A for equivalent serum levels.

HIV thus leads to the establishment of an increasingly vicious cycle, with food insecurity (reduced access and increased need) heightening susceptibility to HIV exposure and infection, and HIV in turn heightening vulnerability to food insecurity. At the same time, food intake is an increasingly recognized factor for HAART tolerance and adherence (The World Bank, 2007). While not all wasting among PLWH is caused by lack of food, qualitative and quantitative studies of the needs of people being treated in resource-poor settings often list food as one of their greatest needs (Au *et al.*, 2006; Mshana *et al.*, 2006) The goal of nutrition support for PLWH in need of anti-retroviral therapy (ART) is to stabilize nutritional status prior to and during treatment, help people regain strength, and contribute to improving nutritional status during treatment. In places where food insecurity prevents people from accessing or adhering to treatment regimes, food supports can play an important role in increasing uptake and adherence to treatment (Megazzini *et al.*, 2006).

Most attempts to assess the impacts on the agricultural sectors of hard-hit African countries have been based on micro-level studies in areas known to have high HIV prevalence. Many experiences on the adaptation of agricultural-based interventions to particular vulnerabilities that households affected by HIV/AIDS experience have been summarized in both NGO and UN documents e.g. FAO (2003). This has resulted in a set of commonly cited statements that build on the logic that loss of adult labor due to AIDS causes severe labor constraints in rural households, resulting in less land being cultivated and a shift away from labor intensive and higher value cash crops to less labor intensive, lower value crops, particularly cassava and sweetpotato which have more flexible planting and harvest periods than do grain crops. Labor loss occurs not only as a result of sickness, loss of muscle mass, reduced physical capacity, and premature adult death, but also as a result of its reallocation to nurse the ill, while working capital is siphoned off to pay mounting medical bills. Empirical evidence calls for a more nuanced approach to addressing this issue. Some evidence finds that the primary constraints on rural productivity and livelihoods may be land and cash more than labor. A study in western Kenya, for example, found a variety of impacts on rural agricultural households struggling with the illness or death of an adult. Total household expenditure for death-affected households was US$462 per year, compared with US$199 for illness affected households and just US$21 for non-affected households. Illness-affected and death-affected households spent 56 percent and 61 percent, respectively, of the amount spent on agricultural inputs by non-affected households (Gillespie and Kadiyala, 2005) .

A set of five SSA country studies based on nationally representative agricultural surveys to which a module to capture the effect of prime-age adult illness and death was added concluded that land/labor ratios of many affected households are similar to those of non-affected households, implying that agricultural labor might not be the household's principal production constraint. "Affected" households were not homogeneous: Households with a prime-age female death were more likely to attract a new prime-age adult member and were richer than households with a prime-age male death (Mather *et al.,* 2005). Households losing the head of the household were much more affected negatively than households losing a prime-age adult that was not a head or the spouse of a head. When they compared the *ex post* percentage area overall cultivated to roots and tubers in Mozambique, Rwanda and Zambia, the mean average differences between affected and non-affected households were not significant (Mather *et al.,* 2005). However, in the case of Rwanda, there was a significant increase in production of sweetpotatoes and a decline in beer banana processing (a labor intensive activity) among households with a chronically-ill prime age adult (Donovan and Bailey 2005). Interpretation of data from Southern Africa in terms of whether crop shifts are due to the pandemic is complicated by the acknowledged growth in roots and tuber projects in this region during the past decade due to policy changes to promote these crops for drought-mitigation and food security and changes in output/input price ratios for grain crops relative to roots and tubers (Mather *et al.,* 2005). Clearly, assessing impact of the pandemic on agriculture at the macro-level is a methodologically challenging issue.

As more PLWH are placed on HAART, and AIDS becomes a chronic disease, policy makers are increasingly looking at ways of improving food intake and nutritional status in resource-poor settings that are more sustainable over the longer term than either nutritional supplements or food supply programs (Food and Nutrition Technical Assistance (FANTA) Project and World Food Programme (WFP) (2007). Although vegetable gardens, small animal production, traditional herb cultivation and other activities are increasingly commonplace in community programs, with reported benefits for participants, little more rigorous evidence is available on the impact of agriculture-based programs on HIV progression or AIDS complications. There are clear gender issues that need to be monitored. If ARVs permit more adults to work and they can earn cash from OFSP, perhaps fewer women and girls will be pressed into service as health care providers. If OFSP helps to ease the food security burden on women in HIV/AIDS affected households that too has positive implications.

In some countries, OFSP is already recognized as an excellent source of vitamin A. For example, a recent newspaper article in Kenya stated "The sweetpotato, for instance, is specially recommended for its richness in vitamin A, which is a requirement for HIV/AIDS victims." (Kariuki, 2008). In terms of widespread adoption, the question arises as to whether being seen as a recommended food for HIV/AIDS affected individuals will negatively affect uptake by non-affected individuals due to the stigma still associated with the disease. Ethical challenges also have arisen – extension personnel in Mozambique have reported instances of local leaders and village promoters directly or indirectly implying that eating OFSP will help prevent AIDS infection (Low, personal communication). A similar situation is found in the Lake Zone of Tanzania, an area of high HIV/AIDS prevalence, where OFSP is called "medicinal sweetpotato" (Field visits 2008). Clearly, HIV/AIDS-affected households can benefit from foods that improve food security and nutrition. The extent to which OFSP can meaningfully contribute to those affected households, and whether the best way of reaching them is through programs specifically targeted at HIV/AIDS affected households or just targeting poor rural and peri-urban households in general warrants further investigation.

Future areas of work for consideration:

1) Impacts of HIV/AIDS taste perception and preferences for OFSP varieties, including their digestibility compared to other food sources, among children and women of reproductive age;
2) Advantages and disadvantages of OFSP production versus other agricultural activities in HIV/AIDS-affected households, and ways that the advantages could be increased;
3) Impacts of OFSP production and consumption on energy and Vitamin A intakes of producing households, and of consumption in consuming households;
4) Impact of OFSP on the intra-household division of labor in HIV/AIDS-affected households and the status of young women;
5) Impacts of community involvement in OFSP production and marketing on livelihoods and food security for HIV/AIDS affected households;
6) Impacts of greater OFSP consumption on nutritional status and progression among PLWH, particularly children and women of reproductive age;
7) How the promotion of OFSP as a crop for HIV/AIDS affected households affects its image and acceptability among non-affected households.

Challenge 3.4. Identifying cost-effective models of scaling out integrated OFSP programs

There are few well-tested extension strategies that combine the provision of new varieties, crop management, and changing nutritionally related behavior in the household. Appropriate cost-effective models that can be scaled-out to reach significant numbers of beneficiaries are required and depend on the perceived role of sweetpotato in the diet.

The challenge of technology dissemination and uptake is a field of research in and of itself. In SSA, there have been attempts to transfer models from other parts of the world to SSA countries with mixed success. There are relatively few interventions that have attempted combining provision of new varieties, crop management, and changing nutritionally related behavior in the household. Even fewer have collected and analyzed relevant cost and benefit data for assessing whether the intervention is cost-effective. This dearth of information has hampered investment in food-based initiatives compared to other approaches to combating micronutrient malnutrition as supplementation and food fortification programs have more readily definable benefits and costs structures than do integrated agriculture-nutrition initiatives.

An intervention utilizing sweetpotato is intrinsically linked to how its role is perceived. There are at least seven ways in which sweetpotato is perceived in SSA, varying between and even within different countries:

1) **As a principal staple essential for food security**. Sweetpotato is a daily part of the diet with per capita consumption exceeding 70 kgs/capita per year;
2) **As a secondary or co-staple.** Sweetpotato is eaten 2-4 times a week when it is in season. Per capita consumption varies depending on whether there are 1-2 growing seasons, ranging from 10-40 kgs/capita/year;
3) **As a famine food or disaster-related food.** Sweetpotato often survives when maize fails, hence its reputation as a famine food. Early maturing varieties can be moved in quickly and provide food within 3-4 months in disaster relief efforts providing that planting material can be sourced;
4) **As a "vegetable"**. Sweetpotato is considered as a horticultural crop grown in community, school or home gardens and eaten in small amounts as a complement to the staple food as a vegetable, such as carrots or pumpkin would be;
5) **As a bread substitute or snack food.** Boiled or steamed sweetpotato roots are used principally as breakfast food in lieu of bread or eaten by itself as a snack, particularly by children, during the day;
6) **As a woman's crop.** In most SSA countries, non-commercial sweetpotato production is under the control of women. Projects seeking to target women as producers, potential income earners, and caregivers of young children recognize sweetpotato as an entry point;
7) **As a health food**. Beta-carotene-rich orange-fleshed varieties introduce the new role of sweetpotato as a health food. Interventions wanting to improve the incomes of the poor, and particularly of women, seek to improve marketing opportunities for sweetpotato, either as fresh roots or processed products. The challenges involved with promoting OFSP commercially as a branded product are addressed in the Value Chains Theme paper.

The promotion of OFSP as a nutritious food implies that some kind of nutrition component is required. In her review of 30 agriculture interventions and their impact on nutritional status, Berti *et al.* (2004) found that projects that invested in different kinds of capital (physical, natural, financial, human and social) were more likely to have an impact on nutritional status. The inclusion of nutrition education, taking gender into account, was a particularly critical human capital investment but not might be sufficient to ensure impact on nutritional status.

Field visits in 2008 revealed that many initiatives are underway on a small to medium scale that include OFSP as a component. This reflects the great demand for technologies to address widespread VAD and technologies that target vulnerable groups. In some initiatives, OFSP is the focus of the agriculture intervention; in others it is one crop among several being promoted. Some are just distributing the vines or have OFSP as one of many crops being introduced (agriculture only intervention); others combine agriculture with nutritional awareness campaigns, emphasizing that OFSP is good for health or contains vitamin A; fewer have more intensive nutrition interventions that entail community level programs to change household dietary practices and/or feeding and care practices of young children; some have active market development components; and a handful have associated finance components providing linked savings or credit schemes to their interventions. Yanggen and Nagujja (2006) summarize strategies used in Uganda by a variety of actors.

Table 3.4 provides a summary of 59 existing projects utilizing OFSP in 15 countries as noted during 2008 field visits conducted in May and June. It is not a definitive list by any means, especially for Uganda and Kenya, but provides insights into the types of development efforts (some of which have explicit research components) that are promoting OFSP. By far, the dominant intervention strategy is to promote OFSP alongside other crops (73% of cases) for the benefit of rural households and promote general awareness of the nutritional value of the crop, but do not engage in more intensive nutrition education or market development. Most initiatives at this stage are small in scale, with only 20% of the projects targeting more than 10, 000 direct beneficiary households.

Scaling-out of any intervention is always a challenge, but in the case of OFSP the integrated nature of the intervention provides an additional challenge as nutrition/health interventions have typically been treated institutionally as separate initiatives from agricultural interventions. Moreover, marketing and finance components require an additional set of skills. The key question is whether such scaling-out a fully integrated approach can be done cost-effectively. A major study, known as the Reaching End Users project, is currently underway in Uganda and Mozambique to scale-out an OFSP-focused intervention in agriculture, nutrition, and market development. The intervention was designed to use village-level promoters to supplement extension personnel as a means for reaching a larger number of households. In addition, communities were divided into those that would receive a more intensive intervention (more direct contacts for message transmission for a longer period of time) than other communities. In Uganda, national NGOs are implementing the intervention with significant backstopping from a team with disciplinary expertise in each area and there is one extension agent responsible for all aspects of agriculture, nutrition and marketing. In Mozambique, international NGOs are implementing the intervention, and separate extensionists are assigned for agriculture and nutrition, supervised by separate higher level personnel. There is one higher level agronomist coordinating market development who engages principally with the agriculture extensionists and promoters. Results from this study (due in 2010) will provide insights as to what is the intensity of contact that is needed and what it will cost to succeed in integrating OFSP into the household farming system *and* integrating into the young child diet. The study also will provide insights into developing markets for OFSP in two very different settings —in Mozambique, sweetpotato markets are underdeveloped and transport costs very high; in Uganda, there is a strong, existing marketing system for sweetpotato in which white-fleshed, red-skinned roots predominate and OFSP has to "break into" this competitive market.

Another major initiative reaching large number of households is also in Mozambique. A CIP scientist stationed within the National Institute of Agrarian Research (IIAM) is breeding new, more drought resistant, OFSP varieties in collaboration with Mozambican counterparts and also backstops the multiplication of primary planting material to serve eight provinces in the country and trains partner organizations on multiplication, production techniques and agro-processing. Multiplication plots are maintained by project staff in several provinces and links are made with a wide range of partners (93 district level public sector extension offices and 77 NGOs and CBOs) who purchase the material for further multiplication and/or distribution. In this approach, each partner integrates OFSP into its own programs and in most cases OFSP is not the major focus of the particular programs but part of broader agricultural initiatives, some of which have nutrition components (Andrade *et al.*, 2007). OFSP vines are also used for disaster relief in response to localized droughts and floods. In 2006, after a year of severe drought, a nationally representative survey reported 164,000 households growing OFSP. While small adoption studies have been conducted by the project, no comparative assessment of the performance of different models using OFSP has been done.

In Asia, Helen Keller International (HKI) has taken home gardening (without an OFSP component) integrated with livestock production successfully to scale in Bangladesh, Cambodia, Nepal and the Philippines, indicating that it is possible to go to scale with a garden approach when there is substantial government commitment (Talukder *et al.*, 2000; Bushamuka *et al.*, 2005; Helen Keller International, 2006) In SSA, Faber *et al.* (2006) documented an approach using orange-fleshed sweetpotato as one of many vegetables in community gardens linked to young child growth monitoring programs in South Africa The design of the program aims to ensure a source of vitamin A-rich foods year round as vegetables are often beyond the financial reach of poor households. A nutrition education component is an essential feature in the South African setting as traditionally vegetable consumption was not high in these communities. The South African government has recently incorporated the vegetable garden concept, with OFSP included, into its national school nutrition program. The food production component of the program has the goal of imparting practical skills to students on food production and natural resource management while the goal of the nutrition education component is to empower the children to make healthy lifestyle choices. As of April 2007, 6390 schools country-wide had established gardens. The program works in collaboration with the National Research Program (ARC) and FAO (Maduna, 2008). The major challenges revolve around the management of the gardens themselves. The program is in its initial stages and will generate important lessons regarding public sector support of school garden initiatives.

Clearly there are many potential delivery mechanisms for OFSP. The degree of complexity of the intervention will determine the level of expertise required for implementation and this, in part, drives the kinds of partnerships needed, especially when interventions are scaled to reach a large number of beneficiaries. This undoubtedly will vary by country due to differences in agro-ecological settings and the human and financial capital available to implement, and the level of development of the target populations.

Table 3.4. Summary of type of on-going development projects utilizing OFSP in SSA in 2008.

	Number of projects using OFSP	Scope of the Intervention: Number of projects targeting small, medium, and large Numbers of direct beneficiary Households (HHs)			Model used for the intervention: Number of projects/organizations using different approaches to OFSP introduction (Ag=Agriculture; NutAw=Nutrtion-Awareness only; NutInt (Nutrtion-Awareness + Behavioral Change Component; Mar=Marketing; Fin=Finance (Credit/Savings)									
		Small (<2000 HHs)	Medium (<2000-10,000 HHs)	Large (<10,000 HHs)	Emergency or resettlement: Ag only	Emergency or resettlement: Ag + NutAw	OFSP promotion Ag only	OFSP promotion Ag + NutAw	OFSP promotion Ag + NutInt	OFSP promotion Ag + NutAw + Mar	OFSP promotion Ag +NutInt + Mar	OFSP promotion Ag + Mar	OFSP promotion Ag + NutAw + Fin	OFSP promotion Ag +NutAw + Mar + Fin
Countries														
East and Central Africa														
Kenya	6	3	3	0	0	0	3	0	1	2	0	0	0	0
Uganda	7	1	4	2	2	0	1	1	0	2	1	0	0	0
Ethiopia	2	1	1	0	0	0	2	0	0	0	0	0	0	0
Tanzania	5	4	1	0	0	0	1	0	0	0	1	1	1	1
Rwanda	3	3	0	0	0	0	1	1	0	1	0	0	0	0
Burundi	2	1	0	1	0	0	1	1	0	0	0	0	0	0
Southern AFrica														
Mozambique	15	5	5	5	1	0	2	11	0	1	0	0	0	1
Malawi	2	0	2	0	0	0	0	2	0	0	0	0	0	0
Zambia	5	2	2	1	0	0	3	0	1	0	1	0	0	0
South Africa	4	2	1	1	0	0	2	1	0	0	0	0	0	0
Madagascar	4	3	1	0	0	0	2	1	1	0	0	0	0	0
Angola	0													
Zimbabawe	1	0	1	0	1	0	0	0	0	0	0	0	0	0
West Africa														
Ghana	1	0	0	1	0	0	0	1	0	0	0	0	0	0
Nigeria	0													
Burkina Faso	1	1	0	0	0	0	0	1	0	0	0	0	0	0
Mali	1	0	0	1	0	0	0	0	0	1	0	0	0	0
Niger	0													
Total	**59**	**26**	**21**	**12**	**4**	**0**	**18**	**20**	**3**	**7**	**3**	**1**	**1**	**2**

Table 3.4. Summary of type of on-going development projects utilizing OFSP in SSA in 2008 (continued).

	OFSP focus of intervention		Partnership diversity: Number of projects with involvement of category of organization: CG=CGIAR center; NARS=National Research Pgm; Ext=Public sector extension; CBOs: community-based organizations								
Countries	**OFSP: Only crop promoted**	**OFSP: one of several crops promoted**	**CG**	**NARS**	**International NGOs**	**Local NGOs**	**CBO**	**Public Sector Ag Ext**	**Public Sector Nutrition / Health Ext**	**Private Sector**	**Univ of other advanced research institutes**
East and Central Africa											
Kenya	3	3	2	4	0	4	2	0	1	1	3
Uganda	5	2	2	3	4	4	5	1	0	0	2
Ethiopia	0	2	0	0	2	0	1	1	0	0	0
Tanzania	1	4	0	2	4	4	2	1	1	0	1
Rwanda	0	3	0	3	2	2	3	0	2	0	0
Burundi	1	1	0	1	1	0	1	1	0	0	0
Southern AFrica											
Mozambique	3	12	2	3	12	2	2	7	3	0	1
Malawi	0	2	2	2	2	2	1	2	1	0	0
Zambia	0	5	0	4	3	1	3	3	1	1	0
South Africa	2	2	0	4	0	0	2	2	2	1	1
Madagascar	0	4	0	4	1	0	1	3	0	0	0
Angola											
Zimbabawe	0	1	0	0	1	0	0	1	0	0	0
West Africa											
Ghana	0	1	0	1	0	1	1	1	0	0	1
Nigeria											
Burkina Faso	1	0	0	0	1	0	0	1	0	0	0
Mali	0	1	0	1	1	0	1	0	0	0	0
Niger											
Total	**16**	**43**	**8**	**32**	**34**	**20**	**25**	**24**	**11**	**3**	**9**

Table 3.4. Summary of type of on-going development projects utilizing OFSP in SSA in 2008 (continued).

	Chidren < 6yrs of age	School going children	Women of Reproductive Age	Pregnant Women	HIV affected communities	Refugees or Recently Resettled Populations	Rural Households in General (all members)	Urban Consumers
Countries								
East and Central Africa								
Kenya	1	0	0	0	0	0	5	1
Uganda	1	1	2	0	0	4	3	0
Ethiopia	0	0	0	0	0	0	2	0
Tanzania	0	0	0	0	3	0	2	0
Rwanda	0	0	1	1	1	0	2	1
Burundi	0	0	0	0	0	1	2	0
Southern Africa								
Mozambique	1	1	4	1	2	0	14	0
Malawi	0	0	0	0	0	0	2	0
Zambia	0	0	0	0	1	0	4	0
South Africa	1	1	1	0	0	0	3	0
Madagascar	0	0	0	0	0	0	4	0
Angola								
Zimbabawe	0	0	0	0	0	1	1	0
West Africa								
Ghana	0	0	0	0	0	0	1	0
Nigeria								
Burkina Faso	1	0	1	0	0	0	0	0
Mali	1	0	0	0	0	0	1	0
Niger								
TOTAL	**6**	**3**	**9**	**2**	**7**	**6**	**46**	**2**

Future areas of work for consideration:

1) More in-depth understanding of adoption rates and nutritional impact achieved in programs where OFSP is one of many crops introduced and/or has distinct role in the food system that has yet to be investigated;
2) *Ex-ante* studies of the potential scalability of different delivery systems for OFSP, identify potential bottlenecks and synergies with other components of the intervention;
3) Development of monitoring and evaluation systems that could be realistically implemented in projects going to scale with the perspective of establishing norms to ensure the collection of baseline data essential for evaluating progress and ultimate impact.

REFERENCES

Alloway, **B.J.** 2004. Zinc in soils and crop nutrition. Brussels, International Zinc Association.

Andrade, M.I., Naico, A., Ricardo, J., Ragú, F., Sandramo, A., and Martins, N. 2007. Multiplication and distribution of healthy planting materials from the best cassava and sweetpotato varieties and screening for new genotypes in the South, Center, and North of Mozambique. Final Report. Maputo, Mozambique, Institute of Agrarian Research of Mozambique (IIAM) and the International Institute of Tropical Agriculture (IITA)**:** 84 p.

Au, J.T., Kayitenkore, K., Shutes, E., Karita, E., Peters, P.J., Tichacek, A., and Allen, S.A. 2006. Access to adequate nutrition is a major potential obstacle to antiretroviral adherence among HIV infected individuals in Rwanda. AIDS 20(16): 2116-2118.

Berti, P.R. 2008. Micronutrients and AIDS: A review of the literature and discussion of relevance to Food Fortification in Africa**.** A literature review prepared for the Micronutrient Initiative and HarvestPlus. HealthBridge. Ottawa, Canada.

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

Bouis, H. 2002. A new tool for fighting micronutrient malnutrition. Journal of Nutrition 132 (Symposium: Plant breeding): 491S-494S.

Bradbury, J.H., and Holloway, W.D. 1988. Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific. ACIAR Monograph Ser. No. 6. Canberra.

Bushamuka, V.N., de Pee, S., and Talukder, A. 2005. Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. Food and Nutrition Bulletin 26(1): 17-25.

Donovan, C., and Bailey, L. 2005. Understanding Rwandan households' strategies to deal with illness and death: A propensity score matching approach. HIV/AIDS and Food and Nutrition Security: From Evidence to Action Conference. Durban, South Africa.

Drain, P.K., Kupka, R., Mugusi, F., and Fawzi ,W.W. 2007. Micronutrient in HIV-positive persons receiving highly active antiretroviral therapy. American Journal of Clinical Nutrition 85: 333-345.

Faber, M., Laurie, S., and Venter, S. 2006. Home-gardens to address vitamin A deficiency in South Africa: A food-based approach. Pretoria, ARC-Roodeplaat Vegetable and Ornamental Plant Institute and the Nutritional Intervention Research Unit of the Medical Research Council.

Faintuch, J., Soeters, P.B., and Osmo, H.G. 2006. Nutritional and metabolic abnormalities in pre-AIDS HIV infection. Nutrition 22: 683-690.

Food and Agriculture Organization (FAO). 2003. Incorporating HIV/AIDS considerations into food security and livelihood projects, A guide. Retrieved 19 July 2008, FAO Nutrition Programme Service Division,
(www.fao.org/es/ESN/nutrition/household_hivaids_en.stm
<http://www.fao.org/es/ESN/nutrition/household_hivaids_en.stm>).

Food and Nutrition Technical Assistance (FANTA) Project and World Food Programme (WFP). 2007. Food Assistance Programming in the Context of HIV. Washington D.C., FANTA Project, Academy for Educational Development.

Fuglie, K., and Yanggen, D. In press. Impact of sweetpotato biofortification on vitamin A deficiency in developing countries: an ex-ante economic assessment. Lima, Peru, International Potato Center (CIP).

Gillespie, S., and Kadiyala, S. 2005. HIV/AIDS, food and nutrition security: from evidence to action. Washington D. C., USA, International Food Policy Research Institute (IFPRI)**:** 149 p.

Gruneberg, W.J., Manrique, K., Zhang, D., and Hermann, M. 2005. Genotype x environment interactions for a diverse set of sweetpotato clones evaluated across varying ecogeographic conditions in Peru. Unpublished progress report. Lima, Peru. International Potato Center (CIP).

Haskell, M.J., Jamil, K.M., Hassan, F., Peerson, J.M., Hossain, M.I., Fuchs, G.J., and Brown, K.H. 2004. Daily consumption of Indian spinach (*Basella alba*) or sweet potatoes has a positive effect on total body vitamin A stores in Bangadeshi men. American Journal of Clinical Nutrition 80: 705-714.

Helen Keller International. 2006. Homestead food production for improving micronutrient status of women and children, poverty reduction and promotion of gender equality. Report. New York, Helen Keller International.

Hess, S.Y., Thurnham, D.I., and Hurrell, R.F. 2005. Influence of provitamin A carotenoids on iron, zinc, and vitamin A status. Washington D.C., International Food Policy Research Institute (IFPRI) and the International Center for Tropical Agriculture (CIAT).

Hotz, C., and Brown, K. 2004. Assessment of the risk of zinc deficiency in populations and options for its control. Food and Nutrition Bulletin 25: S95-S203.

Institute of Medicine. 2001. Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington D.C., National Academy Press.

Jaarsveld, P.J. v., Faber, M., Tanumihardjo, S.A., Nestel, P., Lombard, C.J., and Benade, A.J. 2005. Beta-carotene-rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. American Journal of Clinical Nutrition 81: 1080-1087.

Jaarsveld, P.J. v., Marais, D.W., Harmse, E., and Rodriguez-Amaya, D. 2006. Retention of B-carotene in boiled, mashed orange-fleshed sweet potato. Journal of Food Composition Analysis 19: 321-329.

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

Kosambo, L.M., Carey, E.E., Misra, A.K., Wilkes, J., and Hagenimana, V. 1998. Influence of age, farming site, boiling on pro-vitamin A content in sweetpotato (*Ipomea batatas* (L.) Lam) storage roots. Unpublished progress report. Lima, Peru, International Potato Center (CIP).

Kariuki, J. 2008. Now hungry Kenya shifts focus to traditional crops. The East African, Nairobi. 20 July 2008: p. 23.

Kelly, P., Musuku, J., Kafwembe, E., Libby, G., Zulu, I., Murphy, J., and Farthing, M.J. 2001. Impaired bioavailability of vitamin A in adults and children with persistent diarrhoea in Zambia. Aliment Pharmacol. Ther. 15(7): 973- 979.

Low, J.W., Arimond, M., Osman, N., Cunguara, B., Zano, F., and Tschirley, D. 2007a. Ensuring supply and creating demand for a biofortified crop with a visible trait: Lessons learned from the introduction of orange-fleshed sweet potato in drought-prone areas of Mozambique. Food and Nutrition Bulletin 28: S258-S270.

Low, J.W., Arimond, M., Osman, N., Cunguara, B., Zano, F., and Tschirley, D. 2007b. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. Journal of Nutrition 137: 1320-1327.

Maduna, M. 2008. School gardens within the national school nutrition program. Orange-fleshed Sweetpotato Symposium 3rd October 2007. M. Faber, S. Laurie and P. v. Jaarsveld. Pretoria, South Africa, Medical Research Council and the Agricultural Research Council of South Africa**:** 1-3.

Manrique, K., and Hermann, M. 2000. Effects of GxE Interaction on Root Yield and ß-carotene Content of selected Sweetpotato (*Ipomoea batatas* (L.) Lam) Varieties and Breeding Clones. Unpublished progress report. Lima, Peru, International Potato Center (CIP).

Mather, D., Donovan, C., Jayne, T., and Weber, M. 2005. Using empirical information in the era of HIV/AIDS to inform mitigation and rural development strategies: Selected results from African Country studies. MSU International Development Working Paper. Department of Agricultural Economics and the Department of Economics. East Lansing, Michigan, Michigan Statue University. 84: 15 p.

McLaren, D.S., and Frigg, M. 2001. Sight and Life guidebook on vitamin A in health and disease. Basel, Switzerland, Task Force Sight and Life.

Megazzini, K., Washington, S., Sinkala, M., Lawson-Marriott, S., Stringer, E., Krebs, D., Levy, J., Chi, B., Cantrell, R., Zulu, I., Mulenga, L., and Stringer, J. 2006. A pilot randomized trial of nutritional supplementation in food insecure patients receiving antiretroviral therapy (ART) in

Zambia. XVI International AIDS Conference. Toronto, Canada, August 13-18, 2006, Abstract MoAb0401.

Mshana, G.H., Wamoyi, J., Busza, J., Zaba, B., Changalucha, J., Kaluvya, S., and Urassa, M. 2006. Barriers to accessing antiretroviral therapy in Kisesa, Tanzania: a qualitative study of early rural referrals to the national program. AIDS Patient Care STDS 20(9): 649-657.

Ndirigue, J. 2005. Adaptability and acceptability of orange and yellow-fleshed sweetpotato genotypes in Rwanda. Kampala, Uganda, Makerere University. MSc Thesis: 98 p.

Nestel, P., and Nalubola, R. 2003. The bioavailability of iron from dark green leafy vegetables is low. I. H. N. Institute. Washington D.C., International Life Sciences Institute (ILSI).

Nicklas, T.A., Baranowski, T., Cullen, K.W., and Rittenberry, L. 2001. Family and child-care provider influences on preschool children's fruit, juice and vegetable intake. Nutrition Review 59: 225-235.

Ortaliza, I.C., Salamat, L.A., Cruz, B. de la, Trinidad, T.P., and Jacob, F.O.1974. Iron absorption studies using biologically labeled vegetables. Philippine Journal of Nutrition 27(3): 22-29.

Paterson, D.R., and Speights, D.E. 1971. Effects of foliar applications of iron, manganese, zinc and boron on crop yield and mineral composition of sweetpotato leaf tissue. J. Rio Grande Valley Hort. Soc. 28: 86-90.

Paton, N.I., Sangeetha, S., Earnest, A., and Bellamy, R. 2006. The impact of malnutrition on survival and the CD4 count response in HIV-infected patients starting antiretroviral therapy. HIV Medicine 7(5): 323-330.

Rodriguez-Amaya, D.B., and Kimura, M. 2004. Harvestplus handbook for carotenoid analysis. Harvestplus Technical Monograph 2. Washington D.C. and Cali, International Food Policy Research Institute (IFPRI) and International Center for Tropical Agriculture (CIAT)**:** 58 p. .

Semba, R.D., and Bloem, M.W. 2002. The anemia of vitamin A deficiency: epidemiology and pathogenesis. European Journal of Clinical Nutrition 56: 271-281.

Semba R.D., and Tang, A.M. 1999. Micronutrients and the pathogenesis of human immunodeficiency virus infection. British Journal of Nutrition. Cambrigde University Press. Vol. 81(3):181–189.

Sommer, A., and West, K.P.1996. Vitamin A deficiency: Health, survival and vision. New York, Oxford University Press.

Stein, A.J., Meenakshi, J.V., Qaim, M., Nestel, P., Sachdev, H.P.S., and Butta, Z.A. 2005. Analyzing the health benefits of biofortified staple crops by means of the disability-adjusted life-years approach: a handbook focusing on iron, zinc, and vitamin A. Washington D.C. and Cali, International Food Policy Research Institute (IFPRI) and the International Center for Tropical Agriculture (CIAT).

Talukder, A., Kiess, L., Huq, S., de Pee, S., Darnton-Hill, I., and Bloem, M.W. 2000. Increasing the production and consumption of vitamin A-rich fruits and vegetables: lessons learned in taking the Bangladesh homestead gardening programme to a national scale. Food and Nutrition Bulletin 21(2): 165-172.

The World Bank. 2006. Repositioning nutrition as central to development: A strategy for large-scale actions. Washington D.C.: 246.

The World Bank. 2007. HIV/AIDS, nutrition, and food security: what we can do. A synthesis of international guidance. Washington D.C., USA, The International Bank for Reconstruction and Development (The World Bank).

The World Health Organization (WHO) and the Food and Agriculture Organization (FAO). 2002. Human vitamin and mineral requirements. Rome, FAO.
UNAIDS and The World Health Organization. 2007. *AIDS epidemic update*. Geneva, Switzerland**:** 50 p.

United States Department of Agriculture (USDA), Agricultural Research Service. 2003. USDA National Nutrient Database for Standard Reference, Release 16. Washington, D.C.

West, K.P. 2002. Extent of vitamin A deficiency among preschool children and women of reproductive age. Journal of Nutrition (132): 2857S-2866S.

Wheatley, C., and Loechl, C. 2008. A critical review of sweetpotato processing research conducted by CIP and partners in Sub-Saharan Africa. Social Science Working Paper No. 2008-4. The International Potato Center (CIP). Lima, Peru**:** 48 p.

Woolfe, J.A. 1992. Sweet potato: an untapped food resource. Cambridge, Cambridge University Press.

Yanggen, D., and Nagujja, S. 2006. The use of orange-fleshed sweetpotato to combat vitamin A deficiency in Uganda. Social Science Working Paper No. 2006-2. Lima, Peru, International Potato Center (CIP) 80 p.

Zachariah, R., Fitzgerald, M., Massaquoi, M., Pasulani, O., Arnould, L., Makombe, S., and Harries, A.D. 2006. Risk factors for high early mortality in patients on antiretroviral treatment in a rural district of Malawi. AIDS 20(18): 2355-2360.