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A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women

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Abstract
β-Carotene-rich orange sweet potato (OSP) has been shown to improve vitamin A status of infants and young children in controlled efficacy trials and in a small-scale effectiveness study with intensive exposure to project inputs. However, the potential of this important food crop to reduce the risk of vitamin A deficiency in deficient populations will depend on the ability to distribute OSP vines and promote its household production and consumption on a large scale. In rural Mozambique, we conducted a randomised, controlled effectiveness study of a large-scale intervention to promote household-level OSP production and consumption using integrated agricultural, demand creation/behaviour change and marketing components. The following two intervention models were compared: a low-intensity (1 year) and a high-intensity (nearly 3 years) training model. The primary nutrition outcomes were OSP and vitamin A intakes by children 6–35 months and 3–5·5 years of age, and women. The intervention resulted in significant net increases in OSP intakes (model 1: 46, 48 and 97 g/d) and vitamin A intakes (model 1: 263, 254 and 492 μg retinol activity equivalents/d) among the younger children, older children and women, respectively. OSP accounted for 47–60 % of all sweet potato consumed and, among reference children, provided 80 % of total vitamin A intakes. A similar magnitude of impact was observed for both models, suggesting that group-level trainings in nutrition and agriculture could be limited to the first project year without compromising impact. Introduction of OSP to rural, sweet potato-producing communities in Mozambique is an effective way to improve vitamin A intakes.

Key words: Orange sweet potato: Randomised effectiveness studies: Mozambique: Vitamin A

Vitamin A deficiency is associated with the increased risk of morbidity and mortality, and ocular disorders such as night blindness, xerophthalmia and blindness, affecting infants, children and women during pregnancy and lactation(1). Among populations at risk, vitamin A deficiency is estimated to affect more than 200 million women and children(2). African regions account for the greatest number of preschool children with night blindness and for more than one-quarter of all children with subclinical vitamin A deficiency(2). Interventions to address this deficiency include high-dose vitamin A capsule distribution(3) and, to a lesser extent, vitamin A fortification of foods such as sugar, vegetable oil and fats, and flour(4); nevertheless, the magnitude of vitamin A deficiency remains large.

Although the primary cause of vitamin A deficiency is inadequate vitamin A in the food supply(5), there have been relatively few large-scale, agricultural, food-based interventions implemented to address the problem, and fewer still have been adequately evaluated(6,7). For example, homestead and/or community garden production of vitamin A-rich fruits and vegetables has been promoted in a few populations with some success(6).

Sweet potato is an important staple food crop globally, with higher levels of production in the East African highlands, and

Abbreviations: EAR, estimated average requirement; HAZ, *Z*-scores for height-for-age; LAZ, *Z*-scores for length-for-age; OSP, orange sweet potato; RAE, retinol activity equivalents; USDA, United States Department of Agriculture; WAZ, *Z*-scores for weight-for-age.

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some Asian and South Pacific countries[8]. Sweet potato varieties most commonly cultivated in Africa are white or pale yellow having no or little provitamin A, and have a relatively high DM content[9]. However, provitamin A-rich varieties, known as orange sweet potato (OSP), have been bred through the process of biofortification or have been introduced and evaluated[9,10], and are suitable for Africa in terms of preferred agronomic and consumer traits[10,11]. Due to the high content of β-carotene in some African-grown OSP varieties[12–14], the relatively high seasonal consumption of sweet potato can contribute substantially to increased vitamin A intake adequacy[15,16].

Mozambique is a country with modest use of sweet potato as a staple food[8]. However, the prevalence of vitamin A deficiency is very high, and the coverage of vitamin A supplementation is inconsistent[17]. Zambézia Province in Central Mozambique is more reliant on roots and tubers than on maize, has among the highest rates of stunting and underweight in the country and the lowest rates of vitamin A supplementation[18]. A previous, smaller-scale, quasi-experimental effectiveness study introducing OSP to rural communities in Zambézia Province was successful in increasing OSP and vitamin A intakes among young children, and reducing the prevalence of low serum retinol[19]. However, this relatively intensive intervention may not be feasible or affordable to replicate on a large scale. Research was therefore needed to determine the types and level of inputs required to result in a meaningful and sustainable increase in production and consumption of OSP by vulnerable groups in cost-effective, scalable programmes.

A nearly 3-year long, large-scale intervention to introduce several OSP varieties using agricultural extension and market development activities, product development, combined with demand creation and nutrition education, was implemented in rural communities of Zambézia Province, Mozambique. The study implemented two models of intervention to compare the effect of different durations of inputs on outcomes. Adoption of new practices may be partially dependent on the duration to which individuals are exposed to certain inputs such as direct contact with project staff, but greater inputs also imply greater implementation costs, which is a critical consideration for large-scale programmes. It was hypothesised that intakes of OSP and vitamin A would be greater when exposure to key intervention components was extended to 3 years compared with 1 year. We conducted a prospective randomised, controlled effectiveness study to evaluate and compare the impact of both models. In the present study, we present the impact of both intervention models on the intakes of OSP and vitamin A by children and women. Survey methods and impact results for household adoption of the cultivation of OSP have been presented elsewhere[20].

Experimental methods

Intervention design and implementation

An intervention to introduce household-level cultivation of OSP was implemented between 2006 and 2009 in 144 selected villages from four districts, combined in three strata (Milange, Gurue and Mopeia/Nicoadala) of Zambézia Province, Mozambique. This was a large-scale intervention reaching more than 12 000 farm households and was designed to learn lessons about scaling up the dissemination of OSP. The unit of observation (cluster) was a large farmer group (about 100 households) formed from existing community groups, usually affiliated with one or more churches.

The intervention was adapted from a similar, smaller-scale intervention conducted in the same region[19,21]. The previous intervention reached 1094 direct beneficiaries in fifty-three farmer groups in three districts, whereas the intervention evaluated in the present study represented a large-scale roll-out reaching 10 800 direct beneficiaries. The previous study had more intense contact with households, where four agriculture and four nutrition project extensionists provided community-level inputs, with a beneficiary:extensionist ratio of 274:1 for each component. In the present study, that ratio was 1200:1 and 960:1 for agriculture and nutrition extensionists, respectively, but the extensionists were supported by community-based, volunteer promoters for agriculture (n 108) and nutrition (n 974) activities. These promoters were among the beneficiaries of the intervention.

The intervention integrated three major components. An agricultural component supported the distribution of vines as planting material for OSP, and provided training for improved production practices such as avoidance of pests and diseases and the conservation of vines between annual planting seasons. In the initial vine distribution, farm households were given 2 kg of vines at no cost and, thereafter, were allowed to purchase up to 8 kg of vines. Vine distribution was repeated each year as necessary, as environmental conditions in some areas made it difficult to maintain vines between planting seasons. Additional vines were also made available for purchase. Sweet potato is a crop often farmed by women, therefore both men and women participated in the agriculture component. A demand creation/behaviour change component included education on maternal and child health and nutrition topics targeted to women in participating households, and a campaign for the general public to raise awareness of the benefits of OSP as a source of vitamin A through community drama, field-day events, and radio spots and programmes. A marketing and product development component included training for OSP traders, urban and rural market development for the sale of OSP, and establishment of distinct market stalls selling and providing information on OSP. The market and product development components were not targeted directly to all participating households but were implemented with a smaller group of traders, medium-scale growers and business owners in the general area.

The intervention tested two models of differing intensity. In the 1st year, all three intervention components were implemented in the same manner in both model 1 and model 2 communities. In model 2, the farmer group/household-level activities (i.e. agricultural training, n 4 sessions; health and nutrition education, n 7 sessions) and support from agriculture and nutrition extensionists did not continue beyond the 1st year of implementation, while in model 1 communities, refresher training sessions were continued in the 2nd and 3rd years, with some adjustment according to needs and preferences. Both model 1 and model 2 communities received additional vine distributions and exposure to the broader marketing and promotional components each year.

Country offices of two international non-governmental organisations implemented the intervention: World Vision International led the agricultural and marketing components while Helen Keller International supported the demand creation component, and HarvestPlus (Washington, DC, USA) staff provided overall coordination. The project-employed extensionists who implemented the agricultural extension/marketing and nutrition/health education components trained the community-based volunteer promoters, and these promoters provided training and education to community participants through regular group sessions. Promoters were assisted by the extensionists and received performance-based incentives.

Impact study design

The study was designed as a prospective, randomised intervention at the cluster level, with an impact survey that measured changes between baseline and follow-up. Clusters were randomly assigned to either the model 1 or model 2 intervention group, or a control group. The primary nutrition outcome was change in total vitamin A intake; change in OSP intake and prevalence of inadequate vitamin A intakes were secondary outcomes of interest. Additional study components included anthropometric status and frequency of consumption of selected foods. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Institutional Review Board of the International Food Policy Research Institute (Washington, DC) and by the National Bioethics Committee of the Ministry of Health, Mozambique. Written informed consent was obtained from all subjects.

Site selection

Clusters were selected based on four criteria: (1) number of households with children 6–35 months of age sufficient to meet sample size requirements; (2) access to lowlands to facilitate vine conservation between growing seasons; (3) no other agricultural interventions were being implemented; (4) did not participate in a previous OSP intervention. Additionally, it was ensured that clusters selected for the impact evaluation were at least 5 km apart.

Subjects

Households for the nutrition impact survey were selected from among those in the communities participating in the intervention, and having a resident child 6–35 months of age (hereafter referred to as ‘reference children’), and the child’s mother or other female caretaker (hereafter referred to as ‘women’). The children and women were followed longitudinally and resurveyed 2·5 years after the baseline survey. At follow-up, an additional cross-sectional group of children 6–35 months of age was recruited from the same households, and from additional participant households, and surveyed to enable comparison with the children of the same age at baseline.

Data collection

The baseline nutrition survey was conducted in November–December 2006, before OSP vines were distributed, and the follow-up survey in May–June 2009 during the sweet potato harvest season. Data were collected concurrently across all study groups to avoid bias of seasonal effects on dietary intakes. For the 24 h recall, a 2nd day of recall data was collected for a subset of individuals; for each age group, thirty individuals per study group were targeted. The latter was included to allow estimation of the intra-individual variation in vitamin A intakes, adjusted usual vitamin A intakes and the prevalence of inadequate vitamin A intakes for a subset of non-breast-fed children ≥12 months of age, and women.

Dietary intakes by 24 h recall

All enumerators were intensively trained in interview techniques, probing techniques and specific methods required to conduct the recall. The dietary data collection methods used were adapted from an interactive, multiple-pass method[22]. A group training session for women before the recall interview was conducted to prepare women to observe and recall food types, recipe preparation and portion sizes consumed by them and their participating children. Women were provided with a pictorial chart of common food items to assist in tracking the foods consumed on the day of recall, which was then used as a cross-check during the interview process. In-home interviews were conducted the day after the 24 h period of recall. The first pass of the interview probed for a list of all foods and dishes consumed, in chronological order, and in the second pass, descriptive details were probed such as state (e.g. raw, boiled, roasted), processing method (e.g., chopped, whole) of food consumed and specific ingredients in recipes. In the third pass, women were asked to demonstrate the amounts of foods consumed, amounts of ingredients added to mixed dishes and final mixed dish amounts. In the final pass, information collected was reviewed with the respondents and checked for completeness and correctness.

Portion size recall of sweet potato and all other foods was aided by the use of photographs of different sizes of food items printed to scale, and by real cooked and raw foods whose amounts could be weighed on a digital dietary scale. Volumes were shown by putting equivalent amounts of water or dry rice in household receptacles, or by modelling clay to actual shape and size, after which it was weighed or measured volumetrically. Previously compiled standard recipes were also used for common mixed dishes to minimise respondent burden in recalling details of recipe preparation. Standard recipe data were collected from women in communities following the methods of Gibson & Ferguson[22].

A table of conversion factors was compiled to convert food volumes or sizes to weights representative of the food state as consumed. These factors were either collected systematically in the field, derived from previously collected data in this region or derived from the United States Department of Agriculture (USDA) Nutrient Database[23]. Gram weights of all foods were converted to energy and nutrient intakes using a food composition table compiled for this project. The USDA National Nutrient Database for Standard Reference, version 19[23] was the primary source due to completeness and high standards in relation to sampling and analytic methods, and additional sources were used as necessary. Where nutrient content of raw foods was converted to cooked forms, appropriate water content changes and nutrient retention factors[24] were applied. Sweet potato intakes were converted to raw weight equivalents for presentation.

Food frequency

Women were asked to recall the number of days that specific food items were consumed by their participating child in the last 7 d. The questionnaire included commonly available foods, with a focus on vitamin A-rich foods and fats.

Anthropometry

Weight measurements were taken by field staff, and length or height measurements were taken by supervisors with field staff assistance, following training, piloting and standardisation. Women and children were weighed in light clothing without shoes using electronic scales precise to 0·1 kg (Health O Meter 349KLX; Sunbeam Products Inc., Boca Raton, FL, USA). Length and height were measured using wooden stadiometers (Shorr Board; Shorr Productions LLC, Olney, MD, USA).

Sample size calculation

Data derived from a previous impact study of an intervention to introduce OSP in this area[19,21] were used to determine the appropriate sample size to detect a significant change in vitamin A retinol activity equivalents (RAE) intakes by children. Mean change in vitamin A intakes was found to be 893 (SD 400) μg RAE/d. To detect a change half that size ($\beta = 0{\cdot}80$; $\alpha = 0{\cdot}05$), we estimated that a minimum of thirty-six clusters (twelve per study group) with twelve individuals per cluster, for a total of 432 children, would be required. The same sample size was applied to women.

β-Carotene content of orange sweet potato

From a set of ten possible OSP varieties, six were chosen for distribution as vines in the project based on ranking for agronomic and organoleptic qualities, and β-carotene content. It was not known from the outset which varieties would be most cultivated by households after multiple growing seasons. Since the β-carotene content of OSP is variety-specific, and varietal preferences and agronomic conditions vary by district, we determined a representative mean β-carotene content of the OSP varieties actually grown. OSP was sampled at follow-up from participants' fields in randomly selected intervention communities. It would require twenty-six samples to estimate mean β-carotene content to within 20 % of the expected mean. The OSP variety of greatest abundance in each field was sampled by harvesting three plants from non-border rows and selecting five medium-sized roots to comprise a single sample; this was repeated if the household had a second field planted with a different OSP variety. Samples were catalogued, labelled, washed, air-dried, packed and shipped to the laboratory of the Nutritional Intervention Research Unit of the Medical Research Council, Parow, South Africa, for analysis.

OSP samples were boiled before analysis, as this is the form in which sweet potato is generally consumed in this region. The all-*trans*- and *cis*-β-carotene contents were determined by HPLC following preparation and analytical methods described previously[12] with minor modifications to the extraction solvents and analytical column[25]. District-level data derived from the implementation team on share of vines distributed by variety (%) and previously collected data on variety-specific yields (kg/plant) were combined with variety-specific β-carotene contents. β-Carotene equivalents were calculated as (all-*trans*-β-carotene × 1) + (*cis*-β-carotene × 0·5) and retinol activity equivalency was assumed to be 12:1[26]. The content of energy and all other nutrients for these OSP varieties were derived from the USDA[23] after correcting for difference in water content.

Data management

All data were double-entered using CSPro software (Serpro, Santiago, Chile) and verified. Statistical analyses were performed using Stata (version 11; Stata Corporation, College Station, TX, USA). CSDietary (Serpro) was used to process dietary intake data and C-SIDE (Iowa State University, Ames, IA, USA) was used to estimate usual vitamin A intake distributions and prevalences of inadequate intakes. Anthropometric *Z*-scores for weight-for-height, length- or height-for-age (LAZ or HAZ) and weight-for-age (WAZ) were calculated based on the WHO growth reference data for children <5 years of age[27]. BMI was calculated as weight (kg)/height (m^2).

Statistical analyses

Analyses were carried out using the complex survey module in Stata (Stata Corporation). For each survey round, group differences were tested by two-way comparisons. Impact results were analysed as intention-to-treat, and the difference-in-differences for all two-way group comparisons from baseline to follow-up were calculated, controlling for cluster design and stratifying by district. As breast milk intakes were not measured, the net change in vitamin A and sweet potato intakes assumed equivalent breast milk intakes across the study groups. Data are presented as means with their standard errors or percentages. Although not all outcome variables were normally distributed, impact analyses tested group means. Impact analyses were also conducted using Box–Cox transformed data, but as results did not differ qualitatively, non-transformed data are presented for ease of interpretation.

The Iowa State University method[28] and PC-SIDE (version 1.0; Iowa State University) were used to estimate usual vitamin A intake distributions, best linear unbiased predictors of usual vitamin A intakes at the individual level, and the prevalence of inadequate vitamin A intakes, incorporating the 2nd day of dietary recall data collected for the subset of participants. The Iowa State University method adjusts daily intakes for within-person variability in intakes and the resulting intake distributions reflect only the between-person variance in intakes. The prevalence of inadequate vitamin A intakes was approximated using the estimated average requirement (EAR) cut-point method[29]. The EAR used were 210 μg RAE for children 1–3 years, 275 μg RAE for children 4–8 years, 500 μg RAE for non-pregnant/non-lactating women and 900 μg RAE for lactating women[26]. For the young child age group, children <12 months of age and those still breast-fed were dropped from these analyses because there is no EAR for children <12 months of age[29] and we did not measure breast milk intakes. As there were very few pregnant/non-lactating women, these were combined with non-pregnant/non-lactating women. For estimation of the prevalence of inadequate intakes, usual intakes for lactating women were rescaled to the daily intakes of the non-lactating women by a factor equal to 500/900; this procedure allowed us to use the EAR cut-point method and present one set of prevalence estimates for the full sample of women. This approach is justified because the adjustment of the intake distribution depends on the ratio of within-person and total variance, and hence the scaling factor cancels out. A similar result would be found if prevalence of inadequacy was calculated separately for both groups and a weighted average calculated. A similar method was used for the reference child age group as they straddled two EAR age groups.

Results

For reference children and women, participation rates were 100 % at baseline and attrition rates at follow-up were 9–11 % (Fig. 1). Dietary records for the initial recall were excluded for <3 % of reference children and <1 % of women for baseline and follow-up combined. The sample size for the group of younger children 6–35 months of age at follow-up was smaller than that for children of this age at baseline, due to lower than expected birth rates. The number of individuals for whom a repeated 24 h recall was obtained was adequate at baseline (i.e. *n* 32–41 across age and study groups) but less than the expected 30 at follow-up (i.e. *n* 24–29 across age and study groups). Nonetheless, reasonable variance estimates for vitamin A intakes were obtained with the available data.

At baseline, anthropometric and physiological characteristics of children and women were similar among the study groups (Table 1). The exception was a difference in mean LAZ/HAZ and the prevalence of stunting (LAZ/HAZ < −2 SD). We therefore estimated impacts conditioning on baseline LAZ/HAZ. The prevalence of stunting among children was very high (49–70 %) and the prevalence of underweight (WAZ < −2 SD) was moderate to high (14–24 %), based on the WHO standards[30], and is indicative of widespread chronic and acute malnutrition. The prevalence of underweight (BMI <18·5 kg/m^2) among women was quite low, reaching only 5–8 %.

Examination of the data indicated that primary outcomes differed significantly for individuals from households that included a community-level volunteer promoter. Specifically, change in OSP and vitamin A intakes was greater among individuals from these households compared with those from households where a volunteer promoter did not reside, and hence all impact analyses presented here were controlled to remove this effect. A promoter resided in 22 and 25 % of surveyed households in model 1 and model 2 groups, respectively.

β-Carotene content of orange sweet potato

A total of thirty-two OSP samples were analysed for β-carotene content (Table 2). As varietal preferences varied significantly by region, we calculated the weighted mean β-carotene content separately for Milange/Gurue (north), and Mopeia/Nicoadala (south). The weighted mean β-carotene equivalents content for boiled OSP grown in the southern districts was 24 % greater than in the northern districts.

Dietary sources of energy

At follow-up, maize, rice and sweet potato were the major sources of dietary energy among reference children, together accounting for about 60 % of total energy intakes. All other food sources contributed <10 % of total energy each (Fig. 2).

Sweet potato intakes

Sweet potato was consumed in boiled form; neither the white nor OSP varieties were reported to be used in blended recipes, such as porridges for child feeding, at either baseline or follow-up. At baseline, total sweet potato intakes were relatively low as the dietary survey was conducted outside the peak harvest season, whereas the higher intakes at follow-up represented sweet potato intakes during the harvest season (Table 3). We thus assumed that the relative intake of OSP was the same in both seasons. This assumption was supported by the lack of significant baseline group differences on key household characteristics such as household size, total reported land area, total sweet potato production and total OSP production (Table 1). At baseline, white sweet potato was the predominant type consumed, representing 72–88 % of all types. Some intake of OSP occurred at baseline, representing up to 14 % of all sweet potatoes consumed, and this may have resulted from diffusion from previous OSP projects in the surrounding area.

At follow-up, OSP intake was significantly greater in model 1 and model 2 groups relative to the control, for all three age groups. Although OSP intakes also increased at follow-up in

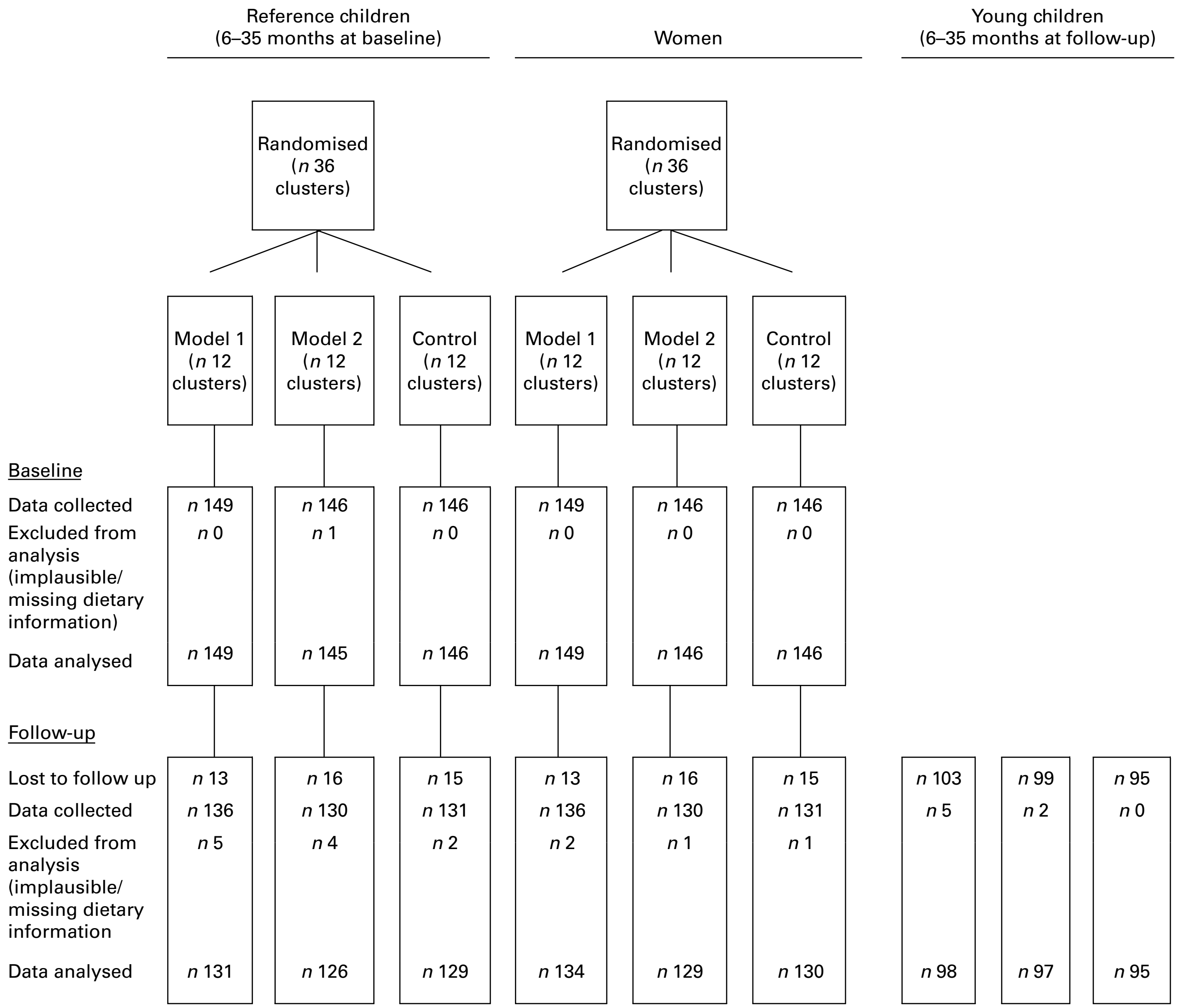

Fig. 1. Participant flow in dietary component of the survey. A total of thirty-six clusters were selected from the programme implementation areas across three districts and allocated to one of the model 1, model 2 or control group. Reference children and women meeting inclusion criteria were recruited from cluster households for the impact survey, and a subset was selected for inclusion in the dietary assessment. Additional young children were recruited from separate households.

the control group, the net change in intakes was still significantly greater in model 1 and model 2 groups relative to the control, as indicated by the impact estimates. A follow-up investigation indicated that the increase in OSP intake in the control group was largely attributed to intakes in one community, and that OSP vines were inadvertently obtained, shared among households, planted and the OSP consumed. The net change in OSP intakes did not differ between the model 1 and model 2 groups. At follow-up, OSP accounted for 47–60 % of all sweet potatoes consumed in the model 1 and model 2 groups across ages, indicating a moderately high degree of substitution for other varieties. In the control groups, 20–24 % of all sweet potatoes consumed were OSP.

Vitamin A intakes

At baseline, vitamin A intakes were relatively low among women and reference children (Table 4). Vitamin A intake data are presented for the single day of dietary recall data (total), and for the adjusted intakes after removing variance attributed to intra-individual variation (total adjusted). At follow-up, vitamin A intakes were significantly higher in the model 1 and model 2 groups compared with the control groups for all age groups. Change in vitamin A intakes among the intervention groups relative to the control was positive and significant for all three age groups, and this was true for both the adjusted and unadjusted data.

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Table 1. Baseline characteristics of participants in an effectiveness study to introduce orange sweet potato (OSP) in rural Mozambique*
(Mean values with their standard errors)

	All		Model 1		Model 2		Control		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	*P*
Young children (6–35 months)									
n	386		131		126		129		
Age (months)	22·4	0·4	22·5	0·8	22·3	0·6	22·3	0·4	0·99
Male (%)	53	3	53	3	51	6	55	5	0·85
Breast-fed (%)	52	3	50	5	53	5	54	4	0·70
Anthropometry									
n	386		131		126		129		
Length- or height-for-age *Z*-score	−2·24	0·10	−1·94	0·13	−2·52	0·13	−2·17	0·15	0·01
Length- or height-for-age *Z*-score < −2 SD (%)	60	4	49	4	70	4	58	4	0·01
Weight-for-age *Z*-score	−1·13	0·07	−1·00	0·10	−1·23	0·09	−1·17	0·12	0·21
Weight-for-age *Z*-score < −2 SD (%)	19	2	14	3	22	2	24	2	0·09
Women									
n	393		134		129		130		
Age (years)	28·9	0·5	29·3	0·8	28·4	0·7	29·1	0·5	0·67
Pregnant (%)	15	2	14	3	15	3	14	5	0·98
Lactating (%)	60	3	63	4	56	5	61	5	0·47
Anthropometry									
n	632		207		208		217		
BMI (kg/m^2)	21·6	0·1	21·5	0·2	21·8	0·3	21·4	0·3	0·64
BMI < 18·5 kg/m^2 (%)	6	2	7	3	5	3	8	2	0·65
BMI > 25 kg/m^2 (%)	8	2	6	1	10	4	7	3	0·30
Households									
n	703		231		236		236		
Household members (*n*)	5·8	0·1	5·7	0·2	5·8	0·1	5·9	0·1	0·73
Total reported land area (ha)	2·0	0·2	2·0	0·2	2·1	0·1	1·9	0·2	0·58
Total sweet potato production (kg)	176	19	161	35	196	43	169	39	0·84
Total OSP production (kg)	7·9	1·6	10·0	2·8	8·1	3·4	5·8	2·9	0·65

* Data are clustered at the farmer group level and stratified by district.

When assessing vitamin A intakes by source, change in the unadjusted intake of vitamin A derived from OSP was positive and significant for both model 1 and model 2 groups relative to change in the control, whereas vitamin A from non-OSP sources did not change significantly (Table 4). This was true for all age groups. Change in vitamin A intakes from OSP or non-OSP sources did not differ between model 1 and model 2. At follow-up, OSP was the dominant source of vitamin A in the diet in the model 1 and model 2 groups combined, providing 71–84 % of all total vitamin A across all groups. Specifically, among reference children, OSP provided 80 % of total vitamin A in the intervention groups combined, and smaller proportions of vitamin A were derived from green leafy vegetables (11 %), yellow sweet potato (3 %), and orange fruits and vegetables, such as pumpkin and papaya (2 %). Similar results were observed for other age groups.

At baseline, the prevalence of inadequate vitamin A intakes was higher among women (80–84 %) than among non-breast-fed reference children 12–35 months of age (36–41 %; Fig. 3). With the exception of the model 1 cohort of children followed longitudinally, there was a significant net reduction in the prevalence of inadequate vitamin A intakes in the intervention groups relative to the control ($P<0·05$).

Intake of energy and other nutrients

The intake of energy and selected nutrients other than vitamin A (i.e. protein, lipid, Ca, Fe, Zn, vitamin C, thiamin, riboflavin, folate and vitamin B_{12}) did not differ between the model 1 or model 2 group and the control at baseline or follow-up (data not shown). The only exception was a significantly lower change in the intake of niacin (−1·15 mg/d; $P<0·05$) in the model 2 group of children 3–5·5 years of age at follow-up, relative to the control.

Discussion

The present large-scale intervention introducing OSP for rural household production and consumption had a substantial impact on the dietary intake of OSP among women and preschool children. The increase in OSP intake in the intervention groups was largely attributed to a direct substitution of white and yellow sweet potato varieties. The incorporation of OSP in the diet translated to a large, significant increase in vitamin A intakes by these subgroups and hence importantly reduced the prevalence of inadequate vitamin A intakes. There were no major differences in the impact on OSP or vitamin A intakes between the model 1 and model 2 groups, indicating that the magnitude of impact observed in the present study was not compromised by the less intensive intervention in model 2.

Following nearly 3 years of project intervention, participating households successfully produced OSP and incorporated it into their diets. An average of 77 % of households across model 1 and model 2 were considered to have adopted OSP for cultivation, representing a 26 percentage point increase in households growing sweet potatoes from the baseline. Among all households growing OSP, an average of 56 % of

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Table 2. Mean β-carotene content of boiled orange sweet potato varieties distributed in an intervention in Mozambique

	Orange sweet potato variety					
	Cordner	Gabagaba	Jonathan*	LO 323	MGCL 01	Resisto
n	1	2	0	5	16	8
β-Carotene equivalents (μg/100 g)†	6793	10 162	5023	5023	9325	11 278
Vitamin A (μg RAE/100 g)	566	847	419	419	777	940
Relative production (kg)‡						
North (Milange and Gurue)	0	0·037	0·152	0·054	0·629	0·127
South (Mopeia/Nicoadala)	0·003	0·068	0	0	0·178	0·752
β-Carotene equivalents (μg/100 g)†						
North (Milange and Gurue)	8716					
South (Mopeia/Nicoadala)	10 842					
Vitamin A (μg RAE/100 g)						
North (Milange and Gurue)	726					
South (Mopeia/Nicoadala)	904					

RAE, retinol activity equivalents.

* The Jonathan variety did not occur in the sampling of orange sweet potato for the analysis of β-carotene content and data were borrowed from LO323 based on these varieties having similar β-carotene content in previous years. Yield was also not determined for Jonathan, and the figure shown was imputed as the average of all other varieties.

† β-Carotene equivalents were calculated as (all-*trans*-β-carotene × 1) + (*cis*-β-carotene × 0·5).

‡ For both north and south districts, relative production (kg) by variety was calculated as the share of vines distributed (%) multiplied by yield (kg/plant), and expressed as a fraction of total vine share × yield.

all sweet potatoes grown was OSP[20], which closely reflected the dietary intake data indicating that 47–60 % of all sweet potatoes consumed were as OSP. Although there was a tendency for a higher intake of total sweet potato among the model 1 and model 2 groups at follow-up, the increase in OSP intake was largely due to the substitution of OSP for white and yellow sweet potatoes. The similar substitution rates across age groups suggest that OSP was equitably shared among the women and children of different ages.

The six OSP varieties introduced in the present study were selected after rigorous testing for agronomic and consumer-preferred traits. After meeting these prerequisites, farmers and consumers were willing to incorporate some of them into their regular production, indicating that the orange colour was not an outright barrier to adoption. The general acceptance of OSP in populations where white or yellow sweet potatoes are usually consumed has been observed elsewhere in sub-Saharan Africa[11,31–33], and can thus be appropriately generalised.

The OSP varieties cultivated had a high content of β-carotene. The mean measured β-carotene content for OSP varieties grown in the northern and southern districts was equivalent to 726 and 904 μg RAE/100 g cooked weight, respectively. This is a much higher vitamin A content than for raw forms of pumpkin (369 μg RAE/100 g), green leafy vegetables (36–259 μg RAE/100 g), mango (83 μg RAE/100 g) and ripe papaya (55 μg RAE/100 g)[23]. As a staple food, sweet potatoes are also eaten in much greater quantities than most fruits and vegetables when they are in season, as indicated by their higher contribution to energy intakes in the present study. A further advantage of focusing on staple foods is that the seasons during which they are available may be longer than for some of the most vitamin A-rich fruits and vegetables, and thus can increase vitamin A intakes over a longer period of time.

Both interventions had a very large impact on mean vitamin A intake, and the adequacy of vitamin A intake in relation to dietary requirements. Based on the adjusted, usual intake

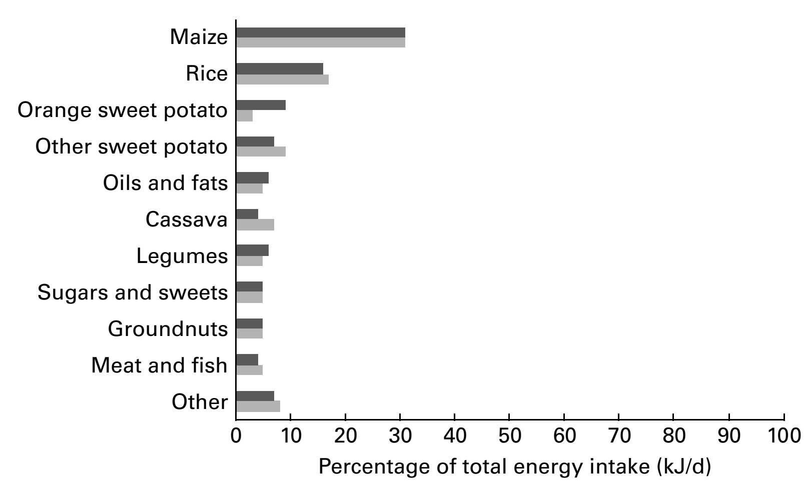

Fig. 2. Dietary sources of energy (kJ) among reference children at follow-up; results for model 1 and model 2 (■) groups combined. ■, Control.

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Table 3. Effectiveness impact of an intervention on intakes of sweet potato by type of sweet potato†

(Means values with their standard errors)

	Baseline‡						Follow-up‡						Impact estimates§					
	Model 1		Model 2		Control		Model 1		Model 2		Control		Model 1 – control		Model 2 – control		Model 1 – model 2	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Sweet potato intakes (g/d)‖																		
Children 6–35 months at baseline																		
n	131		126		129		131		126		129		262		252		258	
White	6·9	2·8	22·7	10·9	6·8	3·8	59·0	13·9	62·3	15·9	61·4	10·0	−2·5	16·3	−18·8	22·6	16·3	25·1
Yellow	1·8	1·6	2·7	2·3	1·6	1·6	9·8	4·6	20·6	7·8	37·5	14·2	−22·4	14·0	−15·9	14·1	−6·5	7·8
Orange	0·4	0·4	0·8	0·8	0·0	0·0	80·7[a]	7·2	72·8[a]	10·0	30·6[b]	8·6	48·3**	12·1	41·1**	13·1	7·2	13·0
Children 6–35 months at follow-up																		
n	–		–		–		98		97		95		229		223		224	
White	–		–		–		31·4	9·0	38·9	7·2	33·5	8·8	−4·5	15·1	−10·4	14·4	5·9	16·3
Yellow	–		–		–		6·2	2·4	4·8	2·3	12·3	4·1	−5·5	5·4	−7·2	4·9	1·7	3·3
Orange	–		–		–		56·1[a]	10·3	47·1[a]	9·1	11·2[b]	5·3	46·1**	12·5	32·2**	11·3	13·9	14·5
Women																		
n	134		129		130		134		129		130		268		258		260	
White	41·0	13·1	65·4	24·2	26·9	14·8	83·7	23·8	89·6	24·5	123·0	23·7	−53·4	34·9	−71·9	34·9	18·5	40·5
Yellow	0·0	0·0	4·6	4·4	1·3	1·3	33·1	13·5	59·9	21·2	73·4	23·3	−39·0	27·3	−16·8	31·4	−22·2	24·0
Orange	2·1	2·0	1·6	1·5	3·8	3·7	143·6[a]	23·4	165·1[a]	22·7	47·9[b]	15·0	97·4**	26·6	119·4**	26·5	−22·0	32·5

[a,b] Mean values with unlike superscript letters within a row for each of the baseline or follow-up surveys were significantly different ($P<0·05$).

Mean values were significantly different from those of the stated comparison groups: ** $P<0·01$.

† Analyses for within-round group comparisons and impact estimates accounted for the complex survey design by clustering at the community level and stratifying by district. Impact estimates represent intention-to-treat effects and were calculated as change in model 1 or model 2 group means minus change in control group mean, or change in model 1 minus change in model 2 group means.

‡ Tests at baseline and follow-up represent pairwise comparisons of means within the survey round.

§ Tests control for group differences in height-for-age *Z*-score at baseline, and for the presence of volunteer community-level promoters in households included in the survey.

‖ Sweet potato weights are raw weight equivalents following conversion from boiled weights.

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Table 4. Effectiveness of an intervention introducing orange sweet potato (OSP) in rural Mozambique on mean intakes of vitamin A as μg retinol activity equivalents (RAE), by source†
(Means values with their standard errors)

	Baseline‡						Follow-up‡						Impact estimates§					
	Model 1		Model 2		Control		Model 1		Model 2		Control		Model 1−control		Model 2−control		Model 1−model 2	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Vitamin A intakes (μg RAE/d)																		
Children 6–35 months at baseline																		
n	131		126		129		131		126		129		262		252		258	
Total	204·3	21·6	198·8	31·8	187·8	21·2	612·9[a]	43·4	570·7[a]	57·9	350·2[b]	67·5	253·7	91·7**	216·3	99·1*	37·5	92·4
Total adjusted‖	223·8	16·9	209·6	11·7	209·6	4·3	540·7[a]	23·1	533·0[a]	16·6	323·5[b]	6·1	202·1	36·3**	206·8	26·1**	−4·7	43·3
OSP source	1·7	1·6	4·6	4·4	0·0	0·0	478·2[a]	41·8	417·3[a]	55·8	188·3[b]	54·1	280·6	74·0**	222·7	76·6**	57·9	71·7
Non-OSP source	202·5	21·9	194·2	29·0	187·8	21·2	134·7	10·5	153·4	16·4	162·0	29·0	−26·9	46·0	−6·4	50·2	−20·5	44·1
Children 6–35 months at follow-up																		
n	–		–		–		98		97		95		229		223		224	
Total	–		–		–		430·2[a]	70·6	380·8[a]	59·4	170·2[b]	46·0	263·2	107·8*	191·4	93·3*	71·7	108·7
Total adjusted‖	–		–		–		410·3[a]	36·5	377·6[a]	26·4	146·5[b]	13·3	261·4	48·7**	232·3	30·3**	29·1	51·9
OSP source	–		–		–		359·5[a]	69·7	273·6[a]	51·4	73·5[b]	37·9	295·0	85·7**	180·6	68·2**	114·4	90·6
Non-OSP source	–		–		–		70·7	9·0	107·3	21·3	96·6	13·9	−31·8	38·1	10·9	42·9	−42·7	38·3
Women																		
n	134		129		130		134		129		130		268		258		260	
Total	504·4	42·8	523·7	87·6	541·3	70·6	1053·9[a]	141·4	1240·2[a]	141·0	599·2[b]	115·9	491·7	192·7*	658·6	194·3**	−167·0	215·5
Total adjusted‖	463·0	16·9	450·1	26·9	478·3	24·4	866·0[a]	69·2	964·4[a]	65·0	660·3[b]	57·9	221·0	96·0**	332·4	89·3**	−111·3	98·7
OSP source	9·6	8·8	9·0	8·7	21·6	21·0	861·0[a]	137·0	967·1[a]	123·0	294·7[b]	91·5	578·3	159·4**	685·0	148·9**	−106·7	182·4
Non-OSP source	494·7	44·2	514·6	83·5	519·7	65·8	192·9	30·9	273·1	40·5	304·5	48·9	−86·6	101·5	−26·4	131·2	−60·2	117·9

OSP, orange sweet potato.
[a,b] Mean values with unlike superscript letters within a row for each of the baseline or follow-up surveys were significantly different ($P<0·05$).
Mean values were significantly different from those of the stated comparison groups: * $P<0·05$, ** $P<0·01$.
† Analyses for within-round group comparisons and impact estimates accounted for the complex survey design by clustering at the community level and stratifying by district. Impact estimates represent intention-to-treat effects and were calculated as change in model 1 or model 2 group mean minus change in control group mean, or change in model 1 minus change in model 2 group mean.
‡ Tests at baseline and follow-up represent pairwise comparisons of means within the survey round.
§ Tests control for group differences in height-for-age *Z*-score at baseline, and for the presence of volunteer community-level promoters in households included in the survey.
‖ Mean vitamin A intakes calculated from a distribution corrected for intra-individual variation, based on a 2nd day of dietary recall data in a subset of individuals. All other intakes presented are unadjusted and derived directly from a single day of dietary recall data per individual. Adjusted data were calculated for a subset of the longitudinal cohort of non-breast-fed reference children 12–35 months of age at baseline (baseline sample size: model 1, *n* 60; model 2, *n* 69; control, *n* 60; follow-up sample size: model 1, *n* 63; model 2, *n* 58; control, *n* 60) and a subset of the cross-sectional group of young children 12–35 months of age at follow-up (follow-up sample size: model 1, *n* 55; model 2, *n* 56; control, *n* 47). The sample size for the longitudinal group of women was the same as presented for unadjusted vitamin A intake data.

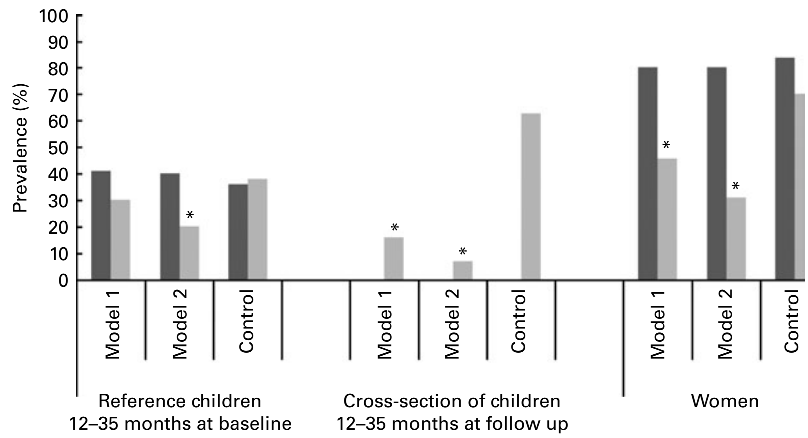

Fig. 3. Effectiveness of an intervention to introduce orange sweet potato in rural Mozambique on the prevalence of inadequate vitamin A intakes. Prevalence data represent intention-to-treat effects for a subset of a longitudinal cohort of reference children 12–35 months of age at baseline (baseline sample size (■): model 1, *n* 60; model 2, *n* 69; control, *n* 60; follow-up sample size (■): model 1, *n* 63; model 2, *n* 58; control, *n* 60), a subset of a cross-sectional group of non-breast-fed young children 12–35 months of age at follow-up (follow-up sample size: model 1, *n* 55; model 2, *n* 56; control, *n* 47) and a longitudinal group of women (baseline sample size: model 1, *n* 134; model 2, *n* 129; control, *n* 131; follow-up sample size: model 1, *n* 134; model 2, *n* 129; control, *n* 130). Statistical differences for change in prevalence in the model 1 and model 2 groups between baseline and follow-up, relative to change in the control group, are indicated by $^{*}P<0{\cdot}05$. Prevalences for the cross-sectional group of children 12–35 months at follow-up were compared with children of the same age at baseline. Prevalences shown for women combine results for all pregnant/non-pregnant and lactating women.

distributions, the net change in mean vitamin A intakes of the intervention groups relative to the control represented increases by 63, 169 and 42 % among reference children, young children and women, respectively. These net increases were equivalent to approximately 74, 118 and 55 % of the corresponding EAR for vitamin A[26] for the same groups, representing a substantial increase in dietary vitamin A.

The estimated prevalences of inadequate vitamin A intakes by these groups commensurately decreased. Among the cohort of reference children followed longitudinally, the change in the prevalence of inadequate vitamin A intakes represented a net decrease of 32 and 55 % in the model 1 and model 2 groups, respectively, although this only reached statistical significance in model 2. For women, although the initial prevalences were higher, results were significant and of a similar magnitude. In the cross-sectional comparisons of young, non-breast-fed children 12–35 months of age, the prevalence of inadequate vitamin A intakes increased in the control group, resulting in a net decrease in the intervention groups of >100 %, bringing the prevalence down to 16 and 7 % in the model 1 and model 2 groups. This is noteworthy as, due to the usually small portion sizes of vitamin A-rich foods consumed by young children and their relatively high requirements, it can be difficult to meet daily dietary vitamin A requirements through locally available, non-fortified foods alone in this region[34,35].

Biochemical or clinical indicators of vitamin A status were not included in the present study; therefore, it is not possible to predict the impact of these increases in vitamin A intake on change in vitamin A status. However, an efficacy trial among South African children has previously indicated that regular consumption of OSP providing 1031 μg RAE/d for 53 d resulted in increased vitamin A stores[36]. One of the main reasons for not including vitamin A status indicators in the present study was that a similar but smaller-scale study in the same area serving as a precursor to the present one had already demonstrated a positive impact on children's serum retinol concentrations following increased intake of vitamin A from OSP and other vitamin A sources[19]. The prevalence of low serum retinol significantly decreased from 60 to 38 % in non-infected children of the treatment group, with no significant reduction in the control group. Rather, the primary objectives were to measure the impacts of a scalable intervention on its adoption and the extent to which this translated into increased OSP and vitamin A intakes among key target groups.

Low *et al.*[19,21] reported a median intake of 314 g/d OSP by children 28–62 months of age at follow-up who consumed OSP on the day of recall, or a mean of about 94 g considering all intervention children. In the present study, children of a similar age (36–67 months) who reported OSP consumption on the day of recall had a median intake of 202 g/d in the intervention groups, and a mean of 46 g for all intervention children. In the previous study, the net increase in median vitamin A intake at follow-up was 370 μg RAE/d, while in the present study, the increase in the combined intervention groups for reference children was 173 μg RAE/d. Therefore, the previous study had a larger overall impact on vitamin A intake than the present study. This is consistent with our initial hypothesis that the present study would have approximately half the impact of the previous study on vitamin A intakes, consequent to the larger scale, which was the basis for our sample size calculation. It is also noteworthy that in the previous study, the increased vitamin A intake was partly attributed to non-OSP sources and increases in energy and other nutrient intakes were observed, resulting from an intensive nutrition education and counselling component. Neither of these effects was observed in the present study, despite the inclusion of nutrition education.

In addition to the previous OSP study[19], there are few other examples of pilot or large-scale programmes introducing strictly plant food sources of vitamin A to communities using combined agricultural and social marketing strategies, where a significant impact on vitamin A status has been observed[37,38]. However, neither of those effectiveness studies used a randomised controlled experimental design, and only one reported quantitative changes in vitamin A intakes measured concurrently with vitamin A status[37].

An intervention to promote and introduce provitamin A-rich fruits and vegetables in rural Thailand resulted in a significant increase in serum retinol concentration among a subset of 10–13-year-old school girls[37]. Vitamin A intakes, expressed as a percentage of the requirement, were presented for a larger group of girls of the same age, but the increase did not differ significantly from the control group, making it difficult to interpret the serum retinol impact in relation to the magnitude of the increase in vitamin A intake. A pilot study introducing provitamin A-rich plant foods in community gardening projects in rural South African communities demonstrated a significant decrease in the prevalence of low serum retinol after 20 months among children 2–5 years of age from 58 to 34 %, with no concurrent change in the control group[38]. In a related study conducted after the 1st year of the project, it has been found that children with project gardens had a vitamin A intake from project fruits and vegetables 450 μg retinol equivalents (equivalent to 225 μg RAE) greater than children without a project garden[39]. If this difference was maintained through the 2nd year of the study when serum retinol was measured, it is just less than the change in vitamin A intake observed among children in the present study of a similar age.

Although these studies resulted in increased vitamin A intakes comparable with those observed in the present study, they were more likely to be maintained throughout the year, whereas OSP are often only available in one growing season in this region of Mozambique. The peak harvest period for sweet potato generally lasts 2–3 months, and piece meal harvesting and staggered planting can extend this to 5 months. OSP as a vitamin A-rich food crop offers a complementary source of vitamin A to help fill the seasonal gaps in vitamin A intakes[40].

In the present study, the increases in OSP intake were similar between the two intervention models. This suggests that additional project inputs to supervise and support the village-level promoters in repeating agriculture and nutrition education sessions through the 2nd and 3rd years of the intervention did not translate into additional impact in the amount of OSP consumed, vitamin A intake or the prevalence of inadequate vitamin A intake. This is an important finding as the additional cost of maintaining direct, community-level contact by project staff beyond the 1st year of intervention is not justified in these sweet potato-producing areas and the maintenance of district-level activities and mass media may be sufficient to maintain behaviour change after the 1st year. We did not identify published reports of similar projects that aimed to directly compare intervention strategies of varying intensity. However, the same result has been found in a related OSP study with a similar design conducted in Uganda[20].

In conclusion, the present large-scale intervention to introduce and promote OSP was successful in incorporating OSP into the diet of women and children, and in significantly increasing the adequacy of vitamin A intakes. OSP is an acceptable, local food source of vitamin A that can easily replace currently grown white or yellow sweet potato varieties. The promotion of OSP in these rural, sweet potato-growing areas in Mozambique can provide a meaningful source of additional vitamin A in a population where vitamin A deficiency is persistently high. Furthermore, we found no differences between a more intensive and a less intensive intervention design, indicating that future interventions to introduce OSP as a source of vitamin A in sweet potato-producing areas of Mozambique can use less intensive intervention models.

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