Vitamin A intakes remain higher among intervention participants 3 years after a biofortification intervention in Mozambique

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Abstract
The Reaching End Users (REU) project introduced orange sweet potatoes (OSP) to farmers in northern Mozambique between 2006 and 2009, and the associated cluster randomised control trial found increased vitamin A intake among targeted children and women of child-bearing age and reduced prevalence of inadequate vitamin A intake. Yet little is known about whether successful agricultural–nutrition interventions have lasting effects. This study measures the lasting effects of the REU project, 3 years after the project ended, on vitamin A intake. To do so, dietary intake data were collected in the same thirty-six villages as the original study, focusing on both women of child-bearing age and children under 6 years old, the latter including both children who had been measured before and younger children (under 3 years old) in the same farmer groups. The dietary intake is then converted to micronutrient intake to compare treated households with control households. Vitamin A intake remains higher in treated villages than in control villages among both children under 3 years old, who had not been born when the original intervention ended, and mothers of child-bearing age. Differences in vitamin A intake can wholly be attributed to differences in OSP intake. Therefore, the REU project appears to have had lasting impacts on vitamin A intake beyond the intervention period. Had the vine retention component been enhanced, lasting impacts could have been even larger.

Key words: Biofortification: Sustainability: Orange sweet potatoes: Mozambique

Interventions that combine agriculture and nutrition are thought to have the potential to improve outcomes in less developed countries, but there only a few interventions that have successfully demonstrated, in a rigorous manner, that nutrition outcomes can be improved through agricultural interventions. Recent reviews of the effectiveness of nutrition-sensitive agricultural programmes suggest that while there have been a wide variety of programmes implemented, only a few randomised evaluations have been conducted that show positive impacts on nutrition outcomes1–5. One such set of evaluations is derived from the Reaching End Users (REU) project in Mozambique and Uganda4–5, which demonstrated the introduction of orange sweet potatoes (OSP) increased vitamin A intake among both targeted children and their mothers and reduced the prevalence of inadequate vitamin A intake in both countries. Further, the evaluation in Uganda showed that children who had been at least mildly vitamin A deficient at baseline were less likely to be vitamin A deficient at end line5.

Although the REU project was successful in the short-term at increasing vitamin A intake among children, it is not known whether the introduction of OSP led to continued positive outcomes among children after the REU project ended. More generally, little is known about how long impacts last from development interventions, as it is rare that data are collected some period of time after an intervention has been completed; exceptions include a nutrition intervention conducted in the 1970s by the Instituto de Nutrición de Centro América y Panamá that followed participants into adulthood6 and medium-run impact estimates of a cash transfer programme developed to keep girls in school7. This paper reports on data collection that took place in 2012 to measure vitamin A intake among beneficiary communities 3 years after the REU project ended.

Abbreviations: EAR, estimated average requirement; OSP, orange sweet potatoes; RAE, retinol activity equivalents; REU, Reaching End Users.

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ended. The primary outcomes studied are vitamin A intake among children aged 6–35 months and their mothers; notably, these children were not yet born at the time the REU intervention ended.

Materials and methods

Project description

The REU project in Mozambique was built on a previous intervention (Towards Sustainable Nutrition Improvement or TSNI; Low et al. (8)) with the goal of reducing vitamin A deficiency through the introduction of OSP. The REU project integrated three components, including a seed systems component to disseminate OSP vines and information about producing OSP, a demand creation component to disseminate information on the importance of consuming OSP and a market component to facilitate exchange of OSP. In Mozambique, the project took place between 2006 and 2009 and involved 144 farmer groups, reaching around 14,000 direct beneficiaries. All farmer groups were located in separate villages to minimise implementation challenges around randomisation for the impact evaluation. The three components were implemented using two models of differing intensity; farmer groups were randomised into the intensive and moderate treatment groups. As the associated impact evaluation found no difference in impact between the two treatment groups (4, 9), the present study combined the two groups. Further, the impact evaluation report found a minimal contribution of the marketing component to average impacts, so it is not discussed in detail below (10).

The seed systems component had three primary tasks. The project grew large quantities of OSP vines for dissemination, distributed multiple varieties of vines to project farmers and taught farmers growing techniques. A hierarchical management structure was designed in which extensionists hired by the REU project trained selected volunteer extension promoters from among farmer group or community group members. These promoters then assisted in vine distribution and trained group members on how to grow OSP and maintain vines between seasons. Farmers therefore had the opportunity to try different varieties and determine which ones they preferred to grow and consume.

The demand creation component used multiple strategies to train and inform people about the nutritional benefits of consuming OSP and other vitamin A sources. Information was conveyed through a variety of sources including group trainings with farmer group members, community theatre sessions related to the health benefits of OSP, radio spots, billboards and other advertising. With regard to extension, the demand creation component had a similar structure to the seed systems component. Nutrition promoters were selected from among farmer or community group members and were trained to deliver nutrition-related messages to their farmer group members. Communication tools were developed to assist nutrition promoters in training farmer group members.

Study design

The impact evaluation associated with the REU project collected data in thirty-six of the 144 farmer groups. For the purposes of this paper, the treatment group includes twenty-four farmer groups that were randomised into the two treatment intensities, and the remaining twelve farmer groups serve as a control group. The control group did receive a distribution of OSP vines in January 2010, with no associated agricultural or nutrition extension.

In 2012, a field team initially returned to all thirty-six treatment and control villages to do a socio-economic survey similar to those completed at baseline (2006) and end line (2009). The socio-economic survey also took place in additional households in each community who had been on farmer group lists, to attempt to learn about diffusion. The socio-economic survey was followed by a dietary intake survey that took place in July and August. The plan had been to field it earlier, in June, but various factors led to delay in commencing the fieldwork. As such, the intakes of OSP are likely to be slightly lower than they would have been in peak harvest months (May and June).

In 2006, households were specifically selected from farmer group lists to have a ‘reference’ child between the age of 6 and 35 months living with them, and socio-economic and dietary intake studies both took place in November and December before vine distribution took place and extension began. Dietary intake was completed with twelve households per farmer group, while the socio-economic survey took place in twenty households per farmer group.

In 2012, the sample was structured as follows. For the socio-economic survey, households were added to attempt to learn about diffusion within the communities. For the dietary intake study, the sample was restricted to only attempt to collect data in households with children aged 6–59 months; households were required to have appeared in the sample either in 2006 or in 2009. Mothers and children were both enumerated in the dietary intake. The fieldwork goal was to reach 400 total households with the dietary intake questionnaire; the final total was 395 children and 346 mothers (Table 1).

In this paper, the primary outcome of interest is vitamin A intake as computed from the dietary intake study, among mothers and children aged 6–35 months. A potential concern among the latter group is that children aged 6–11 months still obtain a substantial amount of vitamin A through breast-feeding. To deal with this concern, we tested whether the proportion of children between the age of 6 and 11 months was statistically different between the treatment and control groups. As the proportions differ neither in 2006 nor in 2012, the results would not be affected by either excluding these children or including an adjustment among these children for breast milk intakes. Nonetheless, they are excluded from estimates of inadequate intake discussed below.

In the present study, the primary nutrition outcome is total vitamin A intake in 2012, after the intervention occurred. The primary outcome is total vitamin A intake, primarily measured among 6- to 35-month-olds and mothers of child-bearing age; the prevalence of inadequate vitamin A intake is a secondary outcome of interest. Additional study components included anthropometric status and frequency of consumption of selected foods. The impact evaluation study was approved by the Institutional Review Board of the International Food Policy
method(11). All enumerators were intensively trained in interview
used were adapted from an interactive, multiple-pass 24-h recall
equate vitamin A intake. The dietary data collection methods
paper to study the medium-term impacts of the REU intervention
Bioethics Committee of the Ministry of Health, Mozambique.
Research Institute (Washington, DC) and by the National
Statistical analyses
Primary analyses were carried out using the complex survey
### Results
First, descriptive statistics for the 2012 sample for selected vari-
A table of conversion factors was compiled to convert food
Table 1. Proportion of households growing orange sweet potatoes (OSP) and children consuming OSP in 2012, Zambezia, Mozambique
(Mean proportions, standard errors; numbers of households)

|                        | Treatment | Control | P  |
|------------------------|-----------|---------|----|
| Grew OSP in 2012, full sample (1 = yes) | 0.268*** | 0.107 | 0.000 |
| n                       | 590       | 307     |
| Grew OSP in 2012, panel sample (1 = yes) | 0.276*** | 0.134 | 0.002 |
| n                       | 217       | 119     |
| Frequency of OSP consumption, 7-d recall (number of days; all children aged 6–59 months) | 0.943** | 0.482 | 0.038 |
| n                       | 262       | 139     |
| Frequency of OSP consumption, 7-d recall (number of days; all children aged 6–35 months) | 0.824** | 0.410 | 0.045 |
| n                       | 153       | 78      |

**P < 0.05, ***P < 0.01.
† Averages presented with their standard errors clustered at the village level and adjusted for stratification.

Measurement
The baseline and 2012 rounds of survey data are used in this
paper to study the medium-term impacts of the REU inter-
don dietary intake of vitamin A as well as the prevalence of in-
dietary data collection methods
were adapted from an interactive, multiple-pass 24-h recall
method(11). All enumerators were intensively trained in interview
techniques, probing techniques and specific methods required to
conduct the recall. Women were provided with a pictorial
chart of common food items to assist in tracking 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 recall period. The first pass of the interview
probed for a list of all foods and dishes consumed, in chronologi-
and in the second pass, descriptive details were
probed such as state (e.g. raw, boiled, roasted), processing
method (e.g. chopped, whole) and specific ingredients in reci-
Portion size recall of all foods, including sweet potato, was aided
using 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 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.

To construct estimates of the best linear unbiased predictors (BLUP) of usual vitamin A intake at the individual level, and the
prevalence of inadequate vitamin A intake, the Iowa State University method was used(14) with PC-SIDE software (version
1.0; Iowa State University). Parameters for adjusting daily intake
for within-person variability in intake were generated for 2012
from the 2006 and 2009 second-day dietary intake; the resulting
intake distributions reflect only the between-person variance in intake. The proportion of individuals in each group with usual
vitamin A intake below the appropriate estimated average require-
ment (EAR) was approximated using the EAR cut point method(15).
The EAR used corresponded to 210 μg retinol activity equivalents
(RAE) for children aged 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 pregnant/lactating women(16). For the young child
age group, children <12 months of age, and breast milk intake was not measured. There were very few pregnant/lactating women in the sample, so these were combined with non-pregnant/non-lactating
women. For estimation of the prevalence of inadequate intake, usual intake for lactating women were re-scaled to the daily intake
of the non-lactating women by a factor equal to 500/900; this
procedure allowed the use of the EAR cut point method and
one set of prevalence estimates for the full sample of women
 included in the survey in 2012 or the strict panel of

Research Institute (Washington, DC) and by the National
Bioethics Committee of the Ministry of Health, Mozambique.

Vitamin A intakes higher after intervention
Table 2. Difference in average vitamin A intake, treatment and control groups, 2012, Zambézia, Mozambique†‡
(Mean values with their standard errors)

|                        | Treatment | Control | P     |
|------------------------|-----------|---------|-------|
| Children under 3 years (n 178) |           |         |       |
| Vitamin A intake (μg RAE) | 264.874** | 147.085 | 0.04  |
| se‡                    | 47.056    | 28.674  |       |
| BLUP (μg RAE)          | 236.610** | 196.562 | 0.032 |
| se‡                    | 12.607    | 12.393  |       |
| Mothers (n 346)        |           |         |       |
| Vitamin A intake (μg RAE) | 626.191*** | 349.107 | 0.004 |
| se‡                    | 68.675    | 43.908  |       |
| BLUP (μg RAE)          | 485.321** | 426.657 | 0.017 |
| se‡                    | 15.000    | 15.215  |       |

RAE, retinol activity equivalents; BLUP, best linear unbiased predictors.
** P≤0.05, *** P≤0.01.
† Source: Mozambique 2012 survey, Reaching End Users project.
‡ Standard errors clustered at the village level and adjusted for stratification.

is necessary, since there is little diffusion of vines between farmer groups. Only three households in the sample reported receiving vines from households in other communities in 2012 (out of 901 households).

The socio-economic questionnaire also asked about the frequency of OSP consumption over the past 7 d among children under 5 years of age. On average, the frequency of consumption is higher among the treatment group compared with the control group, whether the sample is limited to under 3-year-olds (Table 1, rows 3 and 4). The differences are significant at the 5 % level. These questions were asked at a different point in the season than the dietary intake survey, as part of the socio-economic survey; they were asked towards the beginning of the availability period. However, these averages do not control for portion size.

In Table 2, simple differences in average vitamin A intake among children aged 12–35 months and among mothers are presented, both unadjusted and after making the adjustment to the best linear unbiased predictors. Among children under 3 years old, unadjusted intake among the treatment group exceed those among the control group by over 100 μg RAE, and the difference in statistically significant at the 5 % level. Even after vitamin A intake is adjusted to account for within-person variability, intake is higher among the treatment group compared with the control group among both children and mothers, though the unadjusted differences are larger. The same is true among mothers, though the unadjusted difference is much larger.

In Table 3, average differences in unadjusted vitamin A intake between the treatment and control groups are examined using a regression framework. In columns (1)–(3), child characteristics (sex, age) and then household characteristics are sequentially added to the basic regression specification; all results simply reflect average differences in the 2012 data between the treatment and control groups. In columns (4)–(6), a difference-in-difference framework is used, with the 2006 baseline serving as the first round. The interaction between the treatment and the second year gives the treatment effect in columns (4)–(6).

Using the cross-section, the average ‘intention-to-treat’ effect of the REU intervention is found to be between 103·5 and 111·1 μg RAE relative to the control group, and differences between the treatment and control groups are significant at the 5 % level.

The US RDA for vitamin A is 210 μg RAE among children under 5 years old, so the average treatment effect represents about half of the US RDA. Moreover, they suggest that messages about feeding OSP to young children resonated. When the baseline measures are included in the regression, the average intent-to-treat effect drops slightly, to between 89 and 101 μg RAE, depending upon the specification. The point estimate is only significant when all household controls are included (at the 10 % level).

In Table 4, the same pattern is followed to test whether intake is higher in the treatment group compared with the control group among female caregivers of children, as shown in Table 3, using the same methodology as used for children. Using the cross-sectional data, an average treatment effect of around 280 μg RAE is found. The difference is statistically significant at the 1 % level for all specifications in the cross-section and at the 5 % level for all specifications in the difference-in-difference analysis, suggesting it is quite robust.

To contextualise these results, online Supplementary Table S2 (which is Table 4 in Hotz et al.‡) presents differences in change in vitamin A intake among the more intensive intervention model (model 1), the less intensive intervention model (model 2) and the control group between the baseline and end line in 2009. The treatment effect was approximately to 210 μg RAE in 2009 among children aged 12–35 months, suggesting that the difference in 2012 represents a decline in the treatment effect of about 50 % from the project end line. Among female caregivers, the decline in the treatment effect was not quite as large. Average impacts were close to 500 μg RAE in 2009, so the results suggest that impacts on intake are about 60 % high 3 years later. As households received annual vine distributions during the REU intervention, these results are quite positive as they demonstrate an ability of some households to maintain vines.

Changes in vitamin A intake could have come from increased intake of OSP or other foods. Next the source of differences is examined in vitamin A intake among both children under 3 years old and female caregivers (Table 5). Vitamin A sources are disaggregated into three broad categories – orange or yellow sweet potato (or OSP), other plant sources and animal food sources. Among children under 3 years old, the difference in vitamin A intake from OSP is 105 μg RAE between the treatment and control groups, whereas the difference in intake from other plant and animal sources is 8·7 μg RAE and –2·4 μg RAE, respectively; neither difference is statistically significant. As the overall difference is 111 μg RAE, nearly the entire difference between treatment and control groups can be explained by the difference in OSP intake. Similarly, among mothers the difference in vitamin A intake from OSP are 288 μg RAE, which is slightly larger than the total difference of 277 μg RAE. Meanwhile, differences in intake from other plant sources and animal sources are –12·4 μg RAE and 1·9 μg RAE, respectively. So among both children under 3 years and their female caregivers, the difference in intake of vitamin A from OSP effectively explains the total difference in vitamin A intake. In other words, additional OSP intake almost completely explains the difference in vitamin A intake.

To understand a bit better how households sourced OSP in 2012, questions in the socio-economic survey both about production and purchase of OSP were examined. While the survey did not ask whether households received OSP from others
Table 3. Regression results for impacts of the Reaching End Users project on unadjusted vitamin A intakes (μg retinol activity equivalents), using single and double difference, children under 3 years of age, Zambezia, Mozambique†
(Regression coefficients with their standard errors)

|                      | 2012 only | 2006 and 2012 |
|----------------------|-----------|---------------|
|                      | (1)       | (2)          | (3)     | (4)       | (5)       | (6)      |
| Treat                | 111.1**   | 103.5**      | 108.6** | 14:25     | 16:39     | 11:47    |
|                      | 52:00     | 50:00        | 49:59   | 31:56     | 30:25     | 32:63    |
| Treat × post         | 98:66     | 89:61        | 101:9*  | 60:90     | 59:56     | 59:38    |
| Post (year = 2012)   | –54:27    | –56:33*      | –67:88** | 33:19     | 32:31     | 31:95    |
| Male (child; 1 = yes)| –42:04    | –37:82       | –17:71  | –25:86    |
|                      | 55:23     | 51:73        | 22:22   | 24:68     |
| Child age in months  | 6:815***  | –3:948       | 7:834*** | 3:701*    |
|                      | 1:643     | 5:293        | 0:930   | 2:009     |
| Child is breast-feeding (1 = yes) | –213:2** | –80:11*     |
|                      | 104:4     | 42:12        |
| Head is male (1 = yes) | –18:01    | 3:807        |
|                      | 134:6     | 65:59        |
| Age of household head | 2:412     | 1:312        |
|                      | 2:405     | 1:345        |
| Years of schooling, head | 10:93     | 5:089        |
|                      | 6:993     | 4:320        |
| Household has access to wage employment (1 = yes) | –11:26    | 9:303        |
|                      | 63:58     | 29:40        |
| Asset index (PCA)§   | 23:43     | –2:184       |
|                      | 14:68     | 8:947        |
| Constant             | 136:8***  | 3:531        | 207:3   | 191:1***  | 24:63     | 85:49    |
|                      | 26:01     | 4:90         | 164:5   | 20:00     | 29:36     | 84:08    |
| Observations         | 193       | 193          | 180     | 564       | 564       | 486      |
| $R^2$                | 0:029     | 0:061        | 0:133   | 0:017     | 0:085     | 0:101    |

PCA, principal component analysis.
* P < 0.10, ** P < 0.05, *** P < 0.01.
† Source: Mozambique baseline and 2012 surveys.
‡ Standard errors clustered at primary sampling unit and adjusted for sample stratification.
§ The asset index is constructed via PCA and using dichotomous variables that account for the ownership of durable assets of (i) radio, (ii) bicycle, (iii) watch, (iv) bench, (v) chair, (vi) lamp, (vii) portable lantern, (viii) granary, (ix) axe, (x) catana, (xi) latrine, and housing conditions of (xii) whether wall is thatched, (xiii) whether house has window, (xiv) whether general house condition is poor. The variables are chosen in constructing the asset index if they are owned by between 25 and 75 % of households.

Table 4. Regression results for impacts of the Reaching End Users project on unadjusted vitamin A intakes (μg retinol activity equivalents), using single and double difference, mothers, Zambezia, Mozambique†
(Regression coefficients with their standard errors)

|                      | 2012 only | 2006 and 2012 |
|----------------------|-----------|---------------|
|                      | (1)       | (2)          | (3)     | (4)       | (5)       | (6)      |
| Treat                | 277:1***  | 276:6***     | 288:5*** | –20:71    | –22:00    | –27:28   |
|                      | 88:48     | 89:12        | 90:85   | 92:42     | 93:15     | 100:1    |
| Treat × post         | 297:8**   | 298:8**      | 323:5** | 142:0     | 142:8     | 147:9    |
| Post (year = 2012)   | –192:2**  | –193:8**     | –183:7* | 92:94     | 94:27     | 101:3    |
| Head is male (1 = yes) | –312:5    | –86:83       |
|                      | 318:8     | 223:4        |
| Age of household head | 2:196     | –1:496       |
|                      | 6:750     | 3:624        |
| Years of schooling, head | –25:92    | –10:86       |
|                      | 21:59     | 12:43        |
| Mother’s education level (years) | 9:542     | 31:58       | 5:707    | 13:25     |
|                      | 20:38     | 24:47        | 13:18   | 15:87     |
| Household has access to wage employment (1 = yes) | –40:77    | –17:51       |
|                      | 159:0     | 85:97        |
| Asset index (PCA)    | 31:19     | –20:69       |
|                      | 19:67     | 17:22        |
| Constant             | 349:1***  | 335:1***     | 566:5** | 541:3***  | 534:6***  | 691:7*** |
|                      | 43:91     | 55:34        | 257:9   | 70:56     | 71:05     | 192:7    |
| Observations         | 346       | 346          | 325     | 739       | 739       | 649      |
| $R^2$                | 0:024     | 0:025        | 0:044   | 0:017     | 0:017     | 0:025    |

PCA, principal component analysis.
* P < 0.10, ** P < 0.05, *** P < 0.01.
† Source: Mozambique baseline and 2012 surveys.
‡ Standard errors clustered at primary sampling unit and adjusted for sample stratification.
Discussion and conclusion

The results of the 2012 survey demonstrate that targeted household members in farmer groups who participated in the REU project continue to have higher vitamin A intake, caused by increased OSP consumption, compared with household members in the control group. The findings suggest that vitamin A intake was about 111 μg RAE among children in treatment communities aged 6–35 months 3 years after the REU intervention ended, and 277 μg RAE among female caregivers. These differences are about half as large and 60% as large as the average intent-to-treat effects measured from data collected at the project end line (4). While the treatment effects are not as large as they had been, particularly among younger children, the increased vitamin A intake is at least suggestive of lower prevalence of vitamin A inadequacy, though the sample was not large enough to demonstrate this point statistically.

There are several important implications of these findings for future programme design, particularly when combined with further evidence from the project. While casual mediation analysis for the Mozambique data suggested that the adoption decision explained much of the overall project treatment effect on vitamin A intake among children (4), OSP vine receipt is clearly not sufficient to increase vitamin A intake among children. The control group received OSP vines in 2010 without instruction on how to care for them, and vine retention among the control group was particularly low. Therefore, the extension components of the intervention clearly played an important role in helping at least some households maintain vines through the dry seasons between the intervention and the 2012 survey.

Moreover, given the average increase in vitamin A intake among children born after the intervention began, nuanced calculations of cost-effectiveness of the REU project or similar interventions must take into account the future beneficiaries not benefiting during the intervention. An estimate of the average cost per targeted beneficiary was $65, where beneficiaries were defined as either children under 5 years or their female caregivers who were members of households in the intervention communities (4). However, these results show that the next generation of children also benefit, though not as much as during the intervention. Nonetheless, that crude estimate overstates the cost per beneficiary as at least the next cohort of births also benefit.

Finally, improving programming that leads to better vine maintenance or availability could lead to even larger benefits over time after projects end; the gains in vitamin A intake demonstrated in this paper for the treatment group over the control group are averaged over households that were able to retain vines or obtain OSP from neighbours as well as those who could not. The household survey suggested some latent demand for OSP; households continue to report they prefer OSP to other types of OSP in 2012. If more households could continue to grow them, vitamin A intake among young children would likely further increase.

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Socio-economic databases for the paper are available at IFPRI’s Dataverse and the dietary intake data are being processed for public availability through the FAO/WHO Global Individual Food Consumption project. The specific data compiled for use in this paper can be made publicly available ahead of publication.

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A. d. B. was responsible for the impact study design, statistical analysis methods, coordination with the intervention implementation team, interpretation of results and writing the manuscript. M. M. assisted in analysing dietary intake data, performing statistical analyses and with interpreting results. A. B. M. provided overall supervision of the field data collection.

A. d. B. has no conflicts of interest; M. M. was employed by HarvestPlus when the research occurred and when the paper was initially drafted; A. B. M. has no conflicts of interest.

**Supplementary material**

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114519002162

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