Current Developments in Nutrition 7 (2023) 100033

American Society for Nutrition
Excellence in Nutrition Research and Practice

Current Developments in Nutrition

journal homepage: www.journals.elsevier.com/current-developments-in-nutrition

Review

Exploring the Complementarity of Fortification and Dietary Diversification to Combat Micronutrient Deficiencies: A Scoping Review

Aurélie Bechoff [1,*], Julia de Bruyn [2], Arlène Alpha [3], Frank Wieringa [4,5], Valérie Greffeuille [4,5]

[1] *Natural Resources Institute, University of Greenwich, Chatham, United Kingdom;* [2] *Australian Research Council Centre of Excellence for Children and Families over the Life Course, The University of Melbourne, Melbourne, Australia;* [3] *Centre de Recherche Agronomique pour le Développement, Montpellier, France;* [4] *Institut de Recherche pour le Développement, Montpellier, France;* [5] *Unité Mixte de Recherche Qualisud, (alliance between Université Montpellier, Université Avignon, Centre de Recherche Agronomique pour le Développement, Institut Agro, Institut de Recherche pour le Développement and Université de la Réunion), Montpellier, France*

A B S T R A C T

Achieving a balanced and diverse diet remains a challenge for many people, contributing to an ongoing burden of micronutrient deficiencies, particularly in low-income settings. Fortification or dietary diversification are common food-based approaches. We conducted a scoping review to: 1) find evidence on whether combined food–based strategies are more effective than single strategies, and 2) understand how strategies implemented together could complement each other to achieve optimal nutritional impact on populations. Peer-reviewed articles selected ($n = 21$) included interventions or observational studies ($n = 13$) and reviews ($n = 8$). We found little evidence of an added nutritional impact. On the other hand, it is apparent that fortification and dietary diversification target different types of settings (urban compared with rural) and foods (that is, low priced compared with highly priced). Further research is needed to understand the complementarity of these approaches and establish evidence of the effectiveness of combined strategies to foster policy adoption.

Keywords: food diversity, fortification, biofortification, hidden hunger, nutritional impact, integrated food-based strategies

Introduction

Micronutrient deficiencies continue to pose a major global public health problem, particularly in low- and middle-income countries (LMICs), contributing to impaired linear growth of children, reduced immunocompetence, and suboptimal cognitive development, thereby impeding the development of both individuals and societies. A recent study estimates that 1 in 2 preschool aged children, and 2 in 3 women of reproductive age are deficient in ≥1 vitamins or minerals [1]. Despite data gaps, global estimates based on the analysis of existing national surveys reveal that vitamin A deficiency in children has improved in East Asia but remains high in South Asia and Africa [2]. The extent of zinc deficiency remains uncertain due to limited data, but it is estimated to affect >20% of children living in LMICs [3]. Universal iodization of salt has significantly reduced iodine deficiency, but there are 25 countries in which mild to moderate forms of iodine deficiency remain prevalent [4]. In addition, folate deficiency is still a major issue, linked to an estimated 260,100 neural tube defects (including ~175,000 stillbirths and neonatal deaths) [5]. Anemia continues to affect an estimated 41.6% of children and 32.6% of women of reproductive age globally, with data suggesting iron deficiency to be an important, but not the only cause [6,7].

Efforts to combat the burden of these deficiencies over many decades have included a range of nutrition-specific and nutrition-sensitive interventions [8] which can be broadly grouped into four categories: micronutrient supplementation; fortification

Abbreviations used: DD, dietary diversity; IYCF, infant and young child feeding; LMICs, low- and middle-income countries; MNP, micronutrient powder; OFSP, orange fleshed sweet potato.

* Corresponding author. *E-mail address:* a.bechoff@gre.ac.uk (A. Bechoff).

https://doi.org/10.1016/j.cdnut.2023.100033
Received 19 October 2022; Received in revised form 11 January 2023; Accepted 25 January 2023; Available online 28 January 2023

(including biofortification); dietary diversification; and public health and disease control (Figure 1). Fortification and dietary diversification fall under food-based strategies whereas the other two strategies are part of a health approach. These strategies were first described at the International Conference on Nutrition, organized by the FAO and WHO in December 1992 [9]. Biofortification—referred to as micronutrient-enhanced crops by the European Commission—was not developed at this time, but was included in later guidelines [10]. Food-based approaches to improve micronutrient status focus on the consumption of foods that are either naturally rich in micronutrients or have been enriched through fortification [11].

We distinguish different forms of fortification depending on the process and the stage at which micronutrients are added. With industrial fortification, home fortification or food-to-food fortification, micronutrients are added at the site of processing or point of use (consumption), whereas in biofortification, micronutrient content is increased during cultivation, generally using conventional breeding techniques or micronutrient-enhanced fertilizers. Dietary diversification involves increasing the range of foods consumed to better meet the requirements for macro- and micronutrient intake. Although food fortification focuses on increasing the content of one or more specific nutrients in staple foods, dietary diversification typically relates to the introduction or more frequent consumption of nonstaple foods in existing diets.

Industrial fortification and biofortification have gained most attention in nutritional policies, but concerns have been raised about whether promoting fortification as a standalone approach could divert policy makers from other strategies such as supporting diverse and healthy diets [12,13]. Fortification strategies could lead to a limited impact on micronutrient deficiencies, because food fortification is often with a limited number of micronutrients (for example, iodized salt or vitamin A fortified oils), and there are constraints to the amount of micronutrients in biofortified foods that can be achieved through breeding. Likewise, there are challenges linked to the implementation of dietary diversification as a single strategy, as foods naturally rich in micronutrients are often unaffordable for the poorer segments of societies, and linear programming analyses suggest that local foods may be unable to meet nutrient requirements for some population groups in some settings [14–16]. Moreover, producers in rural settings often face various constraints to produce diversified commodities, and the effects of production diversity on smallholder farming households' diets varies between settings [17,18].

To accelerate progress in improving micronutrient status of populations globally, policy recommendations have called for integrating food-based approaches [6,9]. Despite a body of evidence to support the impact on nutritional status of food-based strategies taken separately, there is a knowledge gap about the effectiveness of those actions used in combination [19]. We hypothesize that combining food fortification with diversification of diets would lead to improved nutritional outcomes compared with strategies focusing on either approach alone. The objective of this article is to evaluate the combination, and potential complementarity, of fortification and dietary diversification to improve the micronutrient status of populations.

Methods

Approach

This scoping review follows the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews* guidelines to examine the available literature, consider the scope and types of evidence available, and identify current gaps in the evidence base [20,21]. Our overarching research question asks:

Is there evidence that the two food-based strategies, namely food fortification and dietary diversification, are more effective

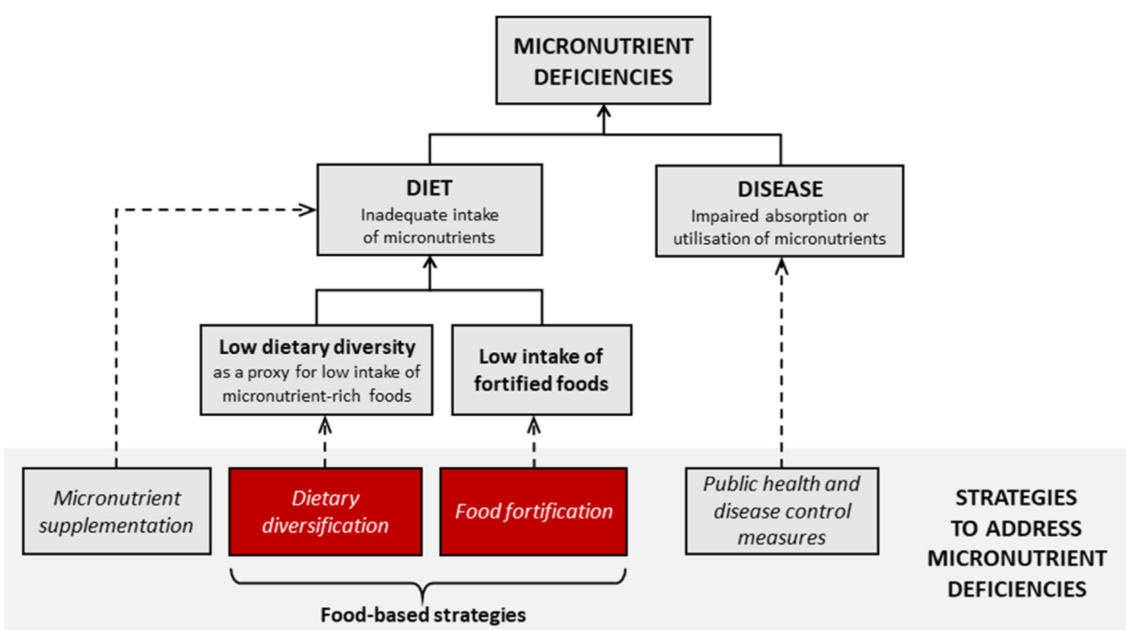

FIGURE 1. Strategies to address micronutrient deficiencies are grouped into four broad categories, three of which address inadequate micronutrient intake and one which targets impaired absorption or utilization. This article focuses on food-based approaches (shaded red). (Source: Authors' own elaboration).

at improving micronutrient intake, status or associated functional outcomes when implemented in combination, compared with either strategy implemented separately?

We respond to this overarching question with three linked subquestions:

1) Is there evidence that combined interventions have an impact on the micronutrient intake, status or associated functional outcomes? (that is, comparing combined interventions with a control group)
2) Is there evidence that combined interventions have a greater impact than single interventions on micronutrient intake, status, or associated functional outcomes? (that is, comparing combined interventions with single interventions)
3) Is there evidence that complementarity of those approaches that leads to a greater impact? (that is, synergistic rather than additive effects)

We also explore factors contributing to program effectiveness:

4) How can program that combine fortification with dietary diversification be implemented most effectively to improve the micronutrient intake, status or associated functional outcomes?

These four subquestions are addressed in separate sections of the results.

Search and sampling strategy

The search was conducted in September-October 2021, using Web of Science, Medline, and Scopus. A further check for recent literature was performed on the same three databases in June 2022, and no additional articles were found. Inclusion criteria required publications to report on the projects and programs that aimed to improve the intake or status of selected micronutrients through both dietary diversification and fortification interventions in one or more LMICs, published in peer-reviewed journals in English or French. Initially, no limits were placed on the date of publication, or on the age and gender of target populations. We included reviews, reviews of reviews, descriptive and inferential analyses, and both quantitative and qualitative research findings.

A search strategy was developed to include terms relating to the two categories of food-based interventions and relevant outcome variables:

Diet diversification: “diet* divers*” OR “food divers*” OR “diet* quality” OR “diverse diet*” OR “nutritious diet*” OR “nutritious food” OR “food-based approach*” OR “food-based strat*” OR “home food” OR “home garden” OR “kitchen garden” OR “community garden” OR “school garden” OR “homestead food” OR “homestead produc*” OR “livestock divers*” OR “agric* divers*” OR “agric* biodivers*“OR “fish divers*” OR “aqua* divers*” OR “nutrition* education” OR “cook* demonst* OR “animal sourc*”

AND

Food fortification: “fortif* OR biofortif*” OR “HarvestPlus” OR “orange sweet potato” OR “orange fleshed sweet potato” OR “orange sweetpotato” OR “orange fleshed sweetpotato” OR “orange maize” or “vitamin A sweet potato” or “vitamin A maize” OR “iron beans” OR “pearl millet” OR “vitamin A cassava” OR “yellow cassava” OR “zinc wheat” OR “zinc rice” OR “golden rice” OR “iodized salt” OR “iodized salt” OR “micronutrient powder” OR “sprinkles”

AND

Outcomes: “micronutrient” OR “vitamin” OR “caroten*” OR “retinol” OR “retinol binding protein” OR “night blindness” OR “xerophthalmia” OR “bitot spots” OR “iron” OR “ferr* compound” OR “ferritin” OR “transferrin” OR “anemia” OR “anemia” OR “hemoglobin” OR “folate” OR “folic acid” OR “spina bifida” OR “neural tube defect” OR “zinc*” OR “nutritional status” OR “anthropom*” OR “diet intake” OR “nutrient intake” OR “morbidity” OR “child growth” OR “iodine” OR “goitre”

Search terms for dietary diversification interventions included terms relating to the broad aim of increasing the range of foods consumed [for example, dietary diversification, dietary diversity (DD), food diversity], categories of interventions that underpin this aim (for example, nutrition education, cooking demonstrations, homestead production) and examples of micronutrient-rich foods that may be targeted (for example, animal-source foods). This recognizes the fact that this strategy is broad, and “dietary diversification” may not be explicitly mentioned in all relevant publications. On the other hand, search terms for (bio)fortification interventions were considered sufficiently defined by including terms relating to this strategy (for example, food fortification or biofortification), as well as specific biofortified crops [for example, orange fleshed sweet potato(OFSP)] or fortification compounds (for example, sprinkles) to encompass all interventions associated with food fortification.

The five micronutrients of interest in this review include iron, zinc, vitamin A, folate, and iodine. We have included studies reporting on the outcomes relating to both micronutrient intake and status, as well as functional outcomes associated with micronutrient status. Indicators of iron status included ferritin and transferrin concentrations, as well as hemoglobin and the prevalence of anemia. For vitamin A deficiency, indicators included retinol and retinol binding protein concentrations, as well as circulating concentrations of provitamin A carotenoids as indirect biomarkers. Included functional outcomes were child stunting and morbidity for zinc deficiency (intentionally nonspecific because zinc deficiency can be reflected in various functional outcomes including child growth [22]); night blindness, xerophthalmia, and bitot spots for vitamin A deficiency; hypercarotenemia for vitamin A excess; spina bifida and neural tube defect for folate deficiency; and goiter for iodine deficiency.

Screening and selection of articles

Screening was carried out between November 2021 and January 2022. Search results were transferred to EndNote referencing software and duplicates removed. The search retrieved 1036 unique articles (Figure 2). The titles and abstracts were searched to identify articles that met fortification as well as diet diversification themes. We excluded studies that pertained to only one of those approaches ($n = 142$ articles on dietary diversification alone, $n = 144$ on fortification alone, $n = 32$ articles exclusively on supplementation), those that did not substantively discuss fortification or dietary diversification ($n = 120$). Only food-based approaches (included fortified complementary foods) were considered and were excluded articles on lipid based nutrient supplements that are nutraceutical. Irrelevant articles,

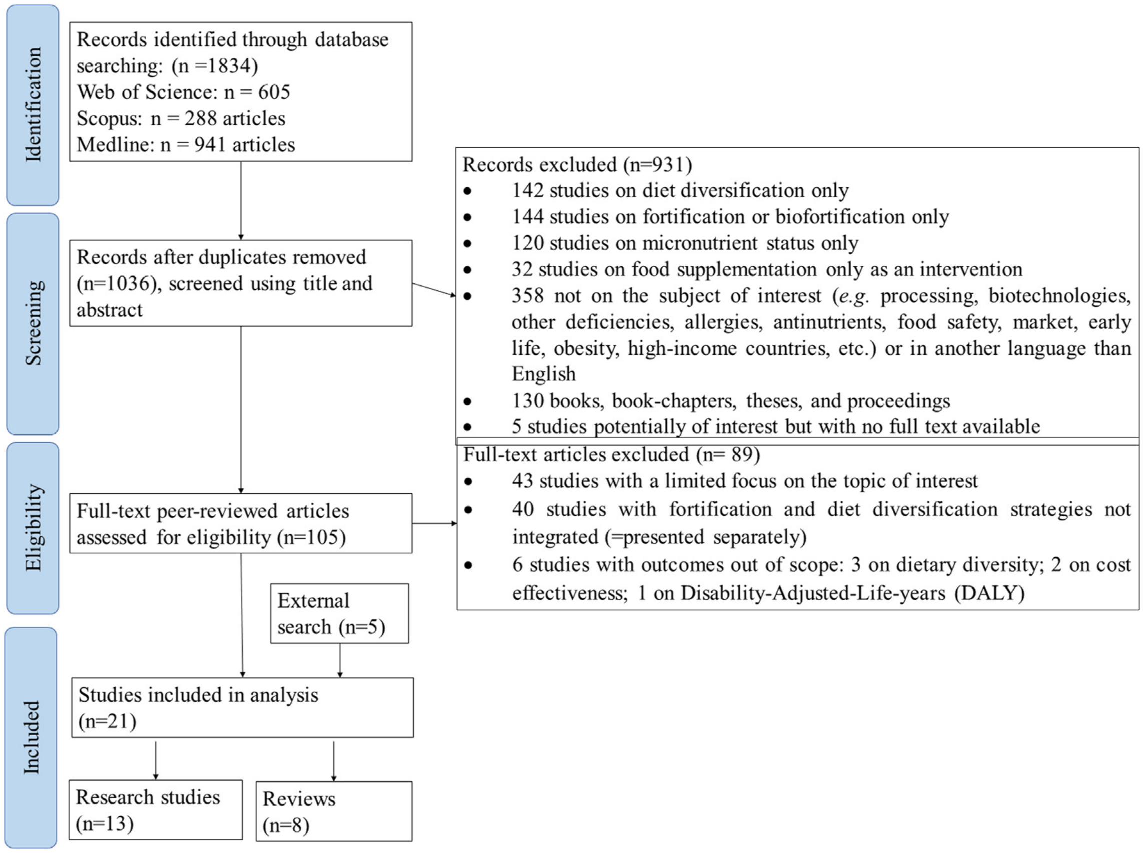

FIGURE 2. Process showing the selection of articles (based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses diagram).

including those not on the topic of interest or in high-income countries (n = 358), books, book chapters, theses, and articles presented in conferences (n = 130), were also rejected. Some full texts were not accessible online (n = 5). Based on titles and abstracts, 109 articles were selected for full-text screening. This included 105 peer-reviewed articles and to this were added five articles from an external nonformal search (that is, based on the authors' knowledge of the relevance of some research studies). Screening was done independently by three authors (AB, JdB, and VG) who agreed on the final selection of 21 peer-reviewed articles including 13 original research articles and eight reviews. The selected articles were examined, and information was extracted by four authors (AB, JdB, VG, and AA). Charting of data involved extraction of details on research design, geographic location, sample size, population group, relevant methods and indicators, key findings, authors, and year of publication.

Results

Characteristics of the studies selected

The primary research studies (n = 13) included eight from Africa (Burkina Faso [23], Burundi [24], Ethiopia [25], Madagascar [26], Malawi [27], Mozambique [28], Uganda [29], and Zambia [30]), four from Asia (Bangladesh [31], Indonesia [32], Nepal [33], and the Philippines [34]), and one from Latin America (Mexico [35]). The studies were published between 2004 and 2020. Only three studies evaluated a *combined intervention* (that is, involving both food fortification and dietary diversification) against a *single intervention* (that is, involving either category alone), whereas 7 studies compared combined interventions with a control group, and three were observational studies that reported outcomes linked to intake of fortified foods and a diverse diet. Interventional studies were largely randomized controlled trials, including both longitudinal studies and repeated cross-sectional assessments. Interventions to diversify diets focused on household food production, school meal programs, nutrition education, and counseling on *infant and young child feeding*. Fortification interventions involved supporting production of biofortified crops, providing fortified complementary foods, flour, oil, or micronutrient powders for home fortification. Only one study reported on micronutrient status as an outcome [36], with others focusing on dietary intake assessments, hemoglobin, or anthropometry.

Of the selected reviews (n = 8), two had a geographic focus on sub-Saharan Africa [37,38] and six provided a global overview [39–44]. The publication years spanned from 2007 to 2021.

Is there evidence that combined interventions have an impact on nutritional outcomes?

Of the seven studies that compared combined or integrated interventions with a control group (Table 1), 6 showed an improved micronutrient-related outcome (that is, anemia, stunting, micronutrient intake) whereas 1 study had mixed results (no overall improvement in the prevalence of stunting, wasting, or anemia, but improved growth in a subset of younger children [23]). The Mexico study [35] was a large-scale cohort study involving 650 children, randomly selected from 347 communities. To evaluate the effectiveness of a large-scale

TABLE 1
Combined interventions compared with control group assessing DD and fortified food intake ($n = 7$)

Reference	Location	Study population and sample size (n)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
Rivera et al., 2004 [35]	Mexico Poor rural communities in six central states	Children <12 mo from low-income households (n = 650) Subset of wider program participants	Randomized controlled trial, with crossover intervention group (intervention delayed by 12 mo)	Fortified food Provision of multi-micronutrient-fortified foods for women and children Diverse diet Conditional cash transfers, requiring attendance at school and health clinics including for mandatory nutrition and health education	Child length, child weight, hemoglobin (Hb) concentration	Mean Hb higher and prevalence of anemia lower in intervention group compared with delayed intervention group in first year. No difference between groups after 12 mo of both receiving intervention. Growth outcomes differed by age and socioeconomic status. For children <6 mo at baseline from poorest households, adjusted height greater by 1.1 cm in intervention group vs. delayed intervention group.	YES on Hb status, anemia, and child length	Potential selection bias due to loss to follow-up. Exposure to program prior to baseline, and in 10% delayed intervention households in first year due to program leakage.
Leroy et al., 2020 [24]	Burundi Rural areas of eastern provinces of Cankuzo and Ruyigi	Children 0–24 mo and 24–42 mo (total of 11,906 observations)	Cluster randomized controlled study, with repeated cross-sectional assessments Four treatment arms: control, and three groups differing in timing and duration of ration provision	Fortified food Provision of monthly ration of micronutrient-fortified corn-soy blend and vitamin A-enriched vegetable oil for (i) first 1000 d, (ii) birth to 18 mo, (iii) birth to 24 mo. Diverse diet Behavior change communication strategy, including peer-led group training sessions on nutrition, including cooking demonstrations Other Improving provision of local health services and promoting their use	Household micronutrient consumption, calculated per male adult equivalent	Higher household consumption of all assessed micronutrients (including iron, vitamin A, zinc, and folate) in each of three intervention groups, compared with control group.	YES on micronutrient consumption as estimated at household level	Training on complementary feeding training module was delayed. Few measures relevant to this review. Micronutrient consumption reported based on household meals, not accounting for individual intake patterns.
Locks et al., 2017 [26]	Madagascar Two rural districts	Children aged 6–23 mo (total of 847 observations)	Repeated cross-sectional assessments (baseline and endline) in participating communities	Fortified food Sale of micronutrient powder (MNP) to mothers by community health workers via a social marketing model, counseling, and radio	Hb concentrations	At endline, almost half children had received MNP, with a median of 30 sachets among those receiving MNP. Reduced risk of anemia: (i) at endline, compared	YES on risk of anemia	Cross-sectional assessments were conducted in different seasons and analysis did not control for seasonal causes of anemia (that is, malaria); but higher

(*continued on next page*)

TABLE 1 (*continued*)

Reference	Location	Study population and sample size (*n*)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
				messages on use of MNP Diverse diet Counseling and radio messages on child feeding, including food diversification and use of local foods		with baseline; and (ii) among children receiving MNP, compared with those not.		prevalence was expected at endline, suggesting possibility of higher risk reduction in diet-related anemia.
Lanou et al., 2019 [23]	Burkina Faso Rural villages in northwest district of Tougan	Children aged 6–23 mo ($n =$ 4629)	Cluster randomized controlled study, with repeated cross-sectional assessments (baseline and endline) Also a nested longitudinal cohort study of children aged 6–11 mo.	Fortified food Provision of mutlimicronutrient powder for home fortification of complementary foods Diverse diet Child-centered counseling (IYCF) and cooking demonstrations, including how to prepare complementary foods from local ingredients	Child length/height, child weight, Hb concentration	No difference in prevalence of stunting, wasting or anemia between control and intervention groups. Hb concentrations decreased in both intervention and control groups at endline, compared with baseline. Children aged 6–11 mo in the nested cohort study had greater length gain in intervention group, compared with control group, but no different in risk of stunting.	Mixed evidence of impact NO on stunting, wasting or anemia prevalence. YES on length gain in subsample of younger children.	Nonnutritional causes of anemia may have masked any possible effects of intervention on iron status. Longitudinal studies of participating households may have been more likely to detect impact on nutritional status than cross-sectional studies. Limited coverage and duration of intervention may have led to underestimation of impact.
Kalimbira et al., 2010 [27]	Malawi Rural communities in North, Central, and South regions	Nonpregnant women of reproductive age (15–49 y, $n =$ 5542) Including current and former program participants	Prospective study with two cross-sectional assessments of program and comparison communities, conducted 4 y apart	Fortified food Introduction of community-level fortification of maize flour (+/− legume blend) with multiple micronutrients, including Fe) Diverse diet Increased production of iron-rich foods (including ASFs, dark green leafy vegetables) and fruits rich in vitamin C and beta-carotene; provision of solar driers for preserving fruits and vegetables Other Prevention, control, and treatment of malaria,	Hb concentration	Comparable prevalence of anemia among women in program and comparison areas at baseline. After 4 y, anemia prevalence had declined in program areas but not in comparison areas. Risk reductions varied with the prevalence of anemia; with significant risk reduction in two of three regions at endline.	YES on prevalence of anemia	Fe/folate supplementation suggested to contribute to decrease in anemia; with uncertainty about relative contribution of other interventions

(*continued on next page*)

TABLE 1 (*continued*)

Reference	Location	Study population and sample size (*n*)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
				hookworm and schistomiasis; weekly Fe-folate supplementation.				
Hotz et al., 2012 (28)	Mozambique Rural communities in central province of Zambézia	Children 6–35 mo at baseline (36–65 mo at endline) and their mothers	Prospective randomized controlled effectiveness study Control group and two intervention groups: (i) low-intensity training model (1 y), (ii) high-intensity training model (3 y).	Fortified food Household-level cultivation of biofortified orange fleshed sweet potato (OFSP) (provision of vines, agricultural training); demand creation / awareness-raising activities about nutritional value of OFSP Diverse diet Training on maternal and child nutrition including DD	Maternal and child nutrient intake	At endline, higher vitamin A intake, overall and from OFSP, by women and children in both intervention groups, compared with control group. No difference in vitamin A intake from foods other than OFSP. No other nutrient intake differences between groups.	YES on vitamin A intake (80% was from OFSP)	Unclear whether nutrition training promoted consumption of a diverse diet and range of nutrient-dense foods, or focused only on OFSP intake.
Hotz et al., 2012 [29]	Uganda Rural communities in Central and Eastern Uganda	Children aged 6–35 mo ($n = 265$) and 3–5 y ($n = 358$) and their mothers ($n = 573$)	Randomized, controlled cluster-design effectiveness study Control group and two intervention groups (2 y): (i) low-intensity training model, (ii) high-intensity training model	Fortified food Household-level cultivation of OFSP (provision of vines, agricultural training); demand creation / awareness-raising activities about nutritional value of OFSP Diverse diet Training on maternal and child nutrition including DD	Maternal and child serum retinol, sweet potato and vitamin A intake, dietary intake	At baseline, OFSP was 2%–6% of total vitamin A. At endline, OFSP contributed to 44%–60% of the total vitamin A intake in the low-intensity and high-intensity models as compared with 5%–11% in the control group. At endline, children from the high-intensity training model had a 9.5 percentage point reduction in the prevalence of serum retinol <1.05 μmol/L. No impact was observed in women.	YES on vitamin A intake for children and women, but only in children for serum retinol	There may have been a confounding effect due to the high prevalence of infection that lessened the impact on vitamin A status. A general trend of declining VAD, linked to improved coverage of fortification and supplementation programs, and a low prevalence of VAD in women presented challenges in measuring intervention impact.

ASFs, animal-source foods; DD, dietary diversity; IYCF, infant and young child feeding; VAD, Vitamin A deficiency.

development program, communities were assigned to an intervention group or a crossover intervention group, with a 12-mo delay in joining the program. The integrated intervention comprised the provision of micronutrient-fortified food for women and children, as well as conditional cash transfers that required attendance at school and health centers, including for mandatory health and nutrition education sessions. The complex and robust design at a large scale resulted in evidence of a significant improvement in anemia prevalence and linear growth among children in communities participating in the program.

A cluster randomized controlled trial in Burundi [24] that targeted women and children in the first 1000 d of life (close to 7000 households) with an integrated program, including fortified food for the child; health services; nutrition education; and *water, sanitation, and hygiene*, reported significant positive impact on the micronutrient intake at a household level. This was also the case for a cross-sectional study in rural Madagascar involving young children and their mothers [26]. There was a reduced risk of anemia in children consuming multi-micronutrient powders, whereas their mothers received counseling on *infant and young child feeding* (IYCF) practices, including encouraging dietary diversification and the use of local foods.

In contrast, a similar randomized controlled trial in Burkina Faso (involving provision of multi-micronutrient powder for home fortification of complementary foods, and IYCF nutrition counseling and use of local foods) did not result in significant differences in anemia prevalence, anthropometry, or morbidity between the treatment and the control groups [23]. The authors hypothesized that a longitudinal study may have been more effective in detecting subtle shifts in child growth than the cross-sectional study used here. There was also a suggestion that the coverage and duration of intervention were suboptimal and not all the children had the same duration of intervention, causing a bias in the trial.

In Malawi, a cross-sectional study [27] offered an integrated package to tackle iron deficiency for nonpregnant women through community-level fortification of flour, and measures to increase access to fruits, vegetables, and animal-source foods, as well as supplementation with iron-folate tablets and prevention and treatment of malaria and endoparasites. This study suggested the prevalence of anemia in program communities reduced after 4 y; however, it was difficult to judge the evolution over time because of the lack of comparable baseline data [27]. Anemia is also a complicated outcome to interpret because of its multifactorial causes [23]. The only two studies reporting on an integrated approach that included biofortification found were randomized controlled trials conducted in Mozambique [28] and in Uganda [29]. Both trials had an intervention package with integrated agricultural, demand creation, and marketing components, with training on maternal and child nutrition as well as inputs and support for production of OFSP, rich in provitamin A. The interventions were associated with significant additional vitamin A intake by women and children in the intervention group, with OFSP accounting for 80% and 44%–60% of total vitamin A intake in endline assessments in Mozambique [28] and Uganda [29], respectively. A follow-up to the Mozambique study identified that vitamin A intake had remained higher in interventional villages than in control villages, 3 y after the intervention had ended [45]. Another article reported on the same intervention in Mozambique and identified low incidence and short duration of diarrhea episodes in children consuming OFSP [46].

Despite one study showing no impact [23,27], there was overall a significant impact on the nutritional outcomes of combined interventions, when compared with a control group.

Is there evidence that the combined interventions are more effective than single interventions in combating micronutrient deficiencies?

Our initial aim in writing this review was to answer the overarching question about the nutritional impact of integrated interventions compared with single interventions. In practice, we found very few trials designed to study the potential synergism between fortification and diet diversification to reduce micronutrient deficiencies (Table 2). Three cluster randomized controlled trials were identified, which all compared dietary diversification as a single intervention with combined interventions including fortification. No study was found on the comparison between fortification alone and combined interventions. In a study on young children in Bangladesh, one treatment arm provided counseling for mothers on child feeding practices (including on quantities and diversity of foods), whereas in four other groups nutrition counseling was accompanied by the provision of different types of complementary food (either local or imported) [31]. The provision of fortified foods was shown to increase micronutrient adequacy of children's diets compared with nutrition counseling alone.

In a study conducted in the Philippines, single intervention focused on dietary diversification, with children given school meals containing indigenous vegetables and nutrition education provided to mothers, whereas in the combined intervention, children also received iron-fortified rice [34]. Children receiving iron-fortified rice had a lower prevalence of anemia and higher mean hemoglobin concentrations, as shown by the baseline values, than the children receiving ordinary rice; with no impact attributed to the single intervention group. In a study conducted in Nepal, single intervention involved a homestead food production program to increase access to nutrient-rich foods (accompanied by nutrition education), whereas the combined intervention also included provision of micronutrient powder for home fortification of complementary foods [33]. In contrast to the study conducted in the Philippines, the Nepal study did not show an added impact of the combined intervention. Neither the single nor the combined intervention yielded any significant impact on child growth, and the effects on anemia were marginal. The authors suggest that insufficient sample size may have resulted in a lack of statistical power to detect significant differences between groups [33]. Therefore, available evidence to support the added benefit of combined interventions over single interventions on micronutrient status is limited.

Is there evidence of complementarity of those approaches that leads to a greater impact?

Although evidence of the added nutritional impact of combined interventions is constrained by the scarcity of appropriately designed studies, another way to approach the question indirectly is to consider evidence of complementarity between fortification and dietary diversification approaches, which would mean that combined interventions could increase their coverage and impact on nutritionally-vulnerable populations.

TABLE 2
Combined interventions (CI) compared with single interventions (SI) assessing dietary diversity and fortified food intake ($n = 3$)

Reference	Location	Study population and sample size (*n*)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
Campbell et al., 2018 [31]	Bangladesh Rural villages in northwest Bangladesh; Gaibandha and Rangpur Districts	Children enrolled at 6 mo, followed to 18 mo	Cluster randomized controlled study Treatment arms: Child feeding counseling encouraging diverse, adequate diet (*SI*); or counseling plus one of four fortified complementary foods as a daily snack for 12 mo (*CI*)	Fortified food Provision of fortified complementary foods, one of four options: commercially-produced Wheat-Soy Blend or *Plumpy'doz*, or locally-produced products based on chickpeas or rice and lentils. Diverse diet Monthly in-home child feeding counseling for mothers, with age-specific messaging about diversity and quantities of complementary foods for children	Micronutrient intake adequacy (measured at three-monthly intervals)	Provision of fortified complementary foods (*CI*) significantly increased mean adequacy ratio for most micronutrients and most ages, compared with counseling alone (*SI*), particularly at older ages. Additionally, minimum dietary diversity was significantly associated with greater odds of adequate intake of iron, zinc, and calcium.	YES on adequacy of micronutrient intake (variation by age and nutrient)	Impact of SI not assessed compared with a nonintervention group (that is, nutrition counseling considered a control group).
Angeles-Agdeppa et al., 2019 [34]	The Philippines Two schools in Cavite Province	Children aged 6–8 y attending primary school, with wasting and/or anemia ($n = 160$)	Cluster randomized controlled study Both schools provided meals with indigenous vegetables (*SI*) for 120 d and nutrition education to mothers; additionally, one school provided iron-fortified rice rather than ordinary rice in school meals (*CI*)	Fortified food School meals containing iron-fortified rice (one school) Diverse food School meals containing indigenous vegetables from school gardens (both schools) Other Nutrition education provided to mothers on health and hygiene, nutrition and gardening (both schools)	Child height, child weight, Hb concentration	Significant weight and height increase in both schools; but greater weight increase in school providing iron-fortified rice (*CI*) compared with ordinary rice (*SI*). Significantly lower prevalence of anemia and higher mean Hb at in school providing iron-fortified rice (*CI*) compared with baseline, and compared with endline in school with ordinary rice (*SI*). No evidence of change in Hb or anemia prevalence attributed to provision of school meals with indigenous vegetables and	YES on prevalence of anemia, Hb status, and weight gain	No measure of child diets outside of school; no assessment of quality of delivery of nutrition education to mothers.

(*continued on next page*)

TABLE 2 (*continued*)

Reference	Location	Study population and sample size (*n*)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
						nutrition education (*SI*)		
Osei et al., 2015 [33]	Nepal Rural community of Baitadi District	Children aged 6–9 mo at baseline (*n* = 306)	Prospective cluster randomized controlled study Treatment arms: (i) enhanced homestead food production (EHFP) alone (*SI*), (ii) EHFP + MNP (*CI*), (iii) control.	Fortified food Provision of MNP containing 15 vitamins and minerals to fortify complementary foods, and counseling on their use Diverse diet EHFP program to increase production and consumption of nutrient-rich fruits, vegetables and animal products (provision of inputs, demonstration plots, nutrition education)	Child weight, child height, Hb concentration	At endline, prevalence of anemia and adjusted mean Hb concentrations decreased, and stunting increased, in all three groups. No significant between-group differences.	NO on anemia prevalence, Hb concentrations or stunting	Small sample size may have reduced power to detect significant differences between groups. Iron status and helminth infections not assessed.

EHFP, enhanced homestead food production; Hb, hemoglobin; MNP, micronutrient powder.

Three observational studies are included in Table 3. A cross-sectional study in Ethiopia [25] showed that inadequate use of iodized salt as well as insufficient DD were associated with goiter. This was linked to poor nutritional practices and implied that an integrated intervention would be beneficial to the population. In another study conducted in Indonesia [32], the consumption of iron-fortified complementary foods led to a decrease in the DD score because those fortified foods partially replaced the nutrient-dense foods; however, children's growth was improved, possibly owing to the micronutrient intake from powdered milk and other fortified foods. The authors highlight an adverse effect of fortification on dietary diversification and warn against an over-reliance on high-cost fortified infant foods, where this may limit children's exposure to a range of textures, flavors, and potentially important bioactive compounds in a varied diet.

Finally, a retrospective cohort study reported on two interventions conducted with a 2-y interval in the same population of children in Zambia [30]: one involving provision of vitamin A supplements and vitamin A biofortified maize, whereas the second involving vitamin A fortified sugar and maize meal. When implemented concurrently with mango season, young children were identified to exhibit hypercarotenemia, illustrating a potential risk of hypervitaminosis A [30]. A study conducted in Ghana and Benin, by Dass et al. [47], reiterates that there may be a risk of overconsumption of vitamin A, folic acid, and niacin in some contexts in supplementation when fortified products are consumed concomitantly. Tanumihardjo et al. [48] described case studies of "overlapping vitamin A interventions" in Guatemala, South Africa, the United States, and Zambia, wherein excessive intakes of vitamin A were also identified.

This shows that multiple intensive interventions or nutritional programs conducted concurrently could also present a health risk when quality control and monitoring of the amount of fortification are not implemented effectively. These three observational studies [24,28,30] demonstrate contrasting nutritional impacts, including the potential for unintended outcomes, and highlight the need for an integrated planning of food-based interventions considering existing diets and settings.

How can these two interventions implemented together complement each other?

Compared with original research studies, information extracted from the reviews offered broader insights into the relative merits and potential complementarity of food-based approaches. The reviews are not country-focused but describe motivations and opportunities to implement integrated food-based approaches (Table 4). Boy et al. [41] discuss fortification, dietary diversification, and supplementation separately for selected micronutrients. For vitamin A, the authors highlight the success of fortification and supplementation programs in reducing eye lesions since the 1990s and acknowledge the broader positive outcomes of homestead garden and nutrition education programs on empowerment and gender equity. In contrast, universal salt iodization is presented as the key strategy to improve iodine intake that should be achieved through political actions (that is, mandatory fortification). For iron, the authors focus largely on supplementation, warning of concerns about negative health effects linked to supplemental iron in places with endemic malaria. With zinc, fortification of

TABLE 3
Noninterventional studies assessing DD and fortified food intake ($n = 3$)

Reference	Location	Study population and sample size (n)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
Abebe et al., 2017 [25]	Ethiopia Urban (9) and rural (4) communities in different ecological zones in northwest Ethiopia from 1000–2500 m above sea level	Children aged 6–12 y attending primary school ($n = 735$)	Observational cross-sectional study	Fortified food Intake of iodized salt Diverse diet Dietary diversity (DD) score	Thyroid physical examination for goiter (functional outcome for iodine deficiency)	High odds of developing a goiter in children with inadequate DD (that is, no fish in diet) and in households with inadequately iodized salt.	YES, both DD and household use of iodized salt associated with reduced risk of goiter.	The study measured iodine intake but did not include biochemical markers (iodine status). Potential for social desirability bias to lead to over-reporting of iodized salt use and handling practices.
Diana et al., 2017 [32]	Indonesia Villages of Sumedang District, West Java. Underprivileged rural settings	Children aged 6–12 mo ($n = 230$), with predominant or exclusive breastfeeding until 6 mo and no signs of chronic disease or acute malnutrition. Followed at 9 mo ($n = 202$) and 12 mo ($n = 190$) of age.	Prospective cohort study Observations of food habits (2-day in-home weighed food intakes)	Fortified food Intake of fortified infant foods (FIFs) Diverse diet Intake of iron-rich foods, intake of nutrient-dense foods, dietary diversity (DD) score.	Child weight, child length, and nutrient intake.	High intake of vitamin A, calcium, and iron (but not zinc) among children consuming FIFs, compared with those not. DD scores positively correlated with nutrient adequacy ratios at 9 mo for all children, and those not consuming fortified foods but not for those consuming fortified foods. At 12 mo, both iron-rich and iron-fortified foods positively associated with linear growth.	Mixed evidence of impact YES, fortified food intake and dietary diversity were associated with high micronutrient intake and length-for-age but DD scores were low in children consuming FIFs	Data collection may have some uncertainties because it relies on short observation (2 d) and breast milk volumes and composition were estimated from literature
Tanumihardjo et al., 2015 [30]	Zambia Poor rural communities with mango trees growing close to the roadside	Preschool children aged 3–5 y at baseline	Retrospective cohort study: observation of 2-intervention studies with the same cohort of children. In the first intervention study, children	Fortified food Biofortified orange maize, fortified sugar, fortified maize flour as part of school meals. Diverse diet High intake of mango owing to seasonal availability	Carotenoids and vitamin A in serum (vitamin A stores)	There no observed impact of the first intervention on vitamin A stores (they were adequate at baseline). However, a year after the second intervention, children close to the	YES, furthermore there is a risk of toxicity if there are too many concurrent interventions	The study was a retrospective observation of fortification and food practices (children eating mango) after the discovery of hypercarotenemia in children. Lack of a structured study

(*continued on next page*)

TABLE 3 (*continued*)

Reference	Location	Study population and sample size (*n*)	Study design	Intervention	Relevant outcome(s) measured	Main findings	Is there evidence of impact?	Limitations
			were given semi-annual vitamin A supplements and biofortified orange maize. After 2 y, in the second intervention, children were fed biofortified maize that had a higher concentration of β-carotene. Sugar in Zambia is also fortified and fortified maize meals are served at school.	Other: Twice-yearly vitamin A supplements in the first year of intervention.		road's skin turned orange indicating an hypercarotenemia and high total body VA stores measured confirmed hypervitaminosis.		design, with several interventions overlapping in different ways over time.

VA, Vitamin A. [1]Noninterventional studies, but evidence of both DD and fortification associated with proxy measures of micronutrient status.

complementary foods and dietary diversification through nutrition education of agricultural interventions (including enhancing access to animal-source foods) are presented as effective actions. Overall, there is limited discussion of integration of the fortification and diversification strategies [41].

Focusing on zinc deficiency, Gibson et al. [43] offer further insights into how different strategies could be applied in different contexts in LMICs, thereby identifying the potential for one strategy to address the limitations of another. National fortification programs of staple cereal flours with zinc could help improve zinc status in countries where deficiency is prevalent. Although fortification is most appropriate for urban households and may be targeted to specific population subgroups (for example, complementary foods for young children), dietary diversification and biofortification are suggested to be suited for the rural poor, who consume foods from local or home production.

Allen et al. [40] emphasize the importance of a diverse diet in meeting requirements for multiple micronutrients, but acknowledge the barriers to physical and economic access to nutrient-rich foods. Fortification is presented as an important complementary strategy for particular nutrients (for example, iodine) and for nutritionally-vulnerable populations (including infants, young children, and pregnant women). The authors note that fortification may be limited by cost, effect of sensory properties, and the accessibility of fortified foods to low-income households. A review by John and Eyzaguirre [39] reflects these concerns, which were common in the early years after biofortification was introduced. These include the potential for a narrowing down of the range of foods that people consume, with a shift away from diverse diets and food systems to a few staple crops. Authors argue that biofortification should fit within a strategy of reinforcing DD in a food system perspective focusing on nutrition and health. A few years later, Hillocks [38] expresses a similar view, contending that biofortified crops should be introduced as supplementary crops with the aim to diversify diet. Both reviews [38,39] convey that biofortification should be integrated into local agricultural systems to diversify the production diversity, as well as DD, in smallholder farming households: to improve the quality of diet and nutrition, biofortified crops should be promoted on the same level as traditional cultivated or wild plants with high nutritive value (leafy vegetables, legumes, fruit trees), for example, as part of homestead production.

Blasbalg et al. [42] describe an integrated approach based on the principle of *econutrition*, contending that undernutrition is best solved through local, ecologically-sustainable, biodiverse agriculture. The authors describe the cycle of poor agricultural practices leading to soil erosion and loss of nutrients and biodiversity, declining agricultural productivity and dietary quality, decreasing labor capacity, and continuing poor agricultural management. Food fortification and supplementation are presented as valuable short-term strategies, and important as ongoing strategies in some cases (for example, salt iodization), but the authors advocate for agricultural approaches for sustainable impact and ensuring *independence for the poor*.

Sharma et al. [44] explore impact pathways in nutrition-sensitive agricultural programs, including biofortification and homestead production. Multisectoral programs with multiple interventions are said to have the potential to

TABLE 4
Overview of review articles discussing the complementarity of food-based interventions ($n = 8$)

Reference	Outcome(s) discussed	Combination(s) considered	Rationale for combined strategies	Recommendations on how to combine strategies	Limitations of the article in regards to evaluating combined strategies
Boy et al., 2009 [41]	Vitamin A, iodine, iron, and zinc intake as well as status	Food-based strategies (both food fortification and dietary diversification) and supplementation; considered separately for each micronutrient.	Vitamin A: Dietary diversification (through nutrition education and horticultural approaches) can have positive outcomes for empowerment and gender equity, as well as nutrition. Carotene-rich sweet potatoes and fortified sugar have been shown to be effective, particularly when complemented by supplementation. Iodine: Universal salt iodization is the key strategy. Dietary diversification is not discussed. Iron: Only mention of food-based strategies is poor design of food fortification programs as a contributing factor to poor control of deficiency. Iron supplementation improves iron status of women during pregnancy and postpartum, as well as for their offspring, but there are concerns about negative health effects (iron supplementation feeding gut parasites) in malaria-endemic areas. Zinc: Fortification of staple foods at the national level or of special foods targeted at specific subpopulations (for example, complementary foods for young children), and strategies to modify diets, to increase bioavailable zinc based on nutrition education or agricultural interventions, are identified as options for improving population zinc status, alongside routine or targeted zinc supplementation.	Strategies are largely discussed separately. For zinc, fortification of complementary foods is recommended for young children, and universal fortification of staple foods is considered an important action in populations with low intake. All strategies to improve zinc status are constrained by a lack of evidence on preventive doses and fortification rates.	Except for Vitamin A, no recommendations to combine strategies.
Gibson et al., 2012 [43]	Zinc intake and status, functional outcomes (stunting, incidence of common illnesses)	Supplementation, fortification (including biofortification), and dietary diversification/ modification.	Strategies are presented as complementary, as one strategy can address the limitations of another strategy. Fortification is most appropriate for urban households and can be implemented at the national level or for specific population subgroups (for example, complementary foods for young children), but their impact may be limited by affordability and accessibility of fortified foods, as well as require continued donor support. Dietary diversification/modification and biofortification are preferred options for the rural	Recommendation is to choose strategies depending on the magnitude of risk, life-stage group, and setting. In all cases, strategies should be integrated with public health programs that address underlying causes of zinc deficiency for maximum impact. Effectiveness depends on political commitment to acceptable, equitable, and sustainable solutions.	The article highlights the strengths of different approaches for particular settings and populations, but does not directly reflect on integration of multiple approaches.

(continued on next page)

TABLE 4 (*continued*)

Reference	Outcome(s) discussed	Combination(s) considered	Rationale for combined strategies	Recommendations on how to combine strategies	Limitations of the article in regards to evaluating combined strategies
			poor, who consume foods from local or home production.		
Allen et al., 2008 [40]	Vitamin A, vitamin B12, folate, iodine, iron, and zinc intake as well as status	Greater dietary diversity in combination with fortification.	A diverse diet provides the many micronutrients needed by humans. Animal-source foods are a rich dietary source of many micronutrients. It may be challenging to meet micronutrient requirements from accessible foods, particularly for infants and young children (for example, iron and zinc) and pregnant women (for example, iron and folate). Fortification is an important complementary strategy, particularly for iodine deficiency (that is, universal salt iodization), but may be limited by cost, effect on sensory properties, and accessibility of fortified foods for low-income households.	Alongside dietary diversification, fortification has its place when applied to a staple food consumed in sufficient amounts by the most vulnerable, and during complementary feeding.	Emphasis is on dietary improvement through intake of micronutrient-rich foods. Fortification is acknowledged as important for particular nutrients and populations, but how to integrate strategies is not discussed.
Johns and Eyzaguirre, 2007 [39]	Malnutrition and nonnutritional outcomes are discussed	Compatibility of biofortification with dietary diversification and its potential impacts from environmental, sociocultural, political, economic, ethical, and biomedical perspectives	Integrated food-based approaches should move beyond single-nutrient staple food interventions. Biofortification should be complemented with greater dietary diversity to overcome challenges in supply of and demand for biofortified crops by poor households, potential negative impacts of further simplification of human diets, and support biodiversity of food systems. Dietary diversification is described as *the more desirable option* to provide multiple micronutrients, but may be limited by cost, whereas biofortification can deliver micronutrients when dietary diversity is impossible.	Biofortification efforts should be focused on local vegetatively propagated species, such as roots and tubers and bananas rather than staple cereals. The introduction of improved genotypes should be implemented with conservation of the traditional crops and biodiversity and in accordance with people's needs and culture with a long-term sustainability approach.	The article does not clearly show how combined interventions could work. Main focus is on how to avoid potential negative impacts of biofortification on dietary diversity.
Hillocks 2011 [38]	Vitamin A, iron, and zinc status; functional outcomes	Multiple crop-based agricultural options for dietary diversification, including biofortified crops	Agricultural approaches to improve dietary quality are recommended as more economical and sustainable than a medicinal approach (that is, supplementation). Four crop-based options are discussed: growing the full range of already available crops, improved varieties with enhanced nutrient content (biofortified), underutilized crops, and wild plants that have high nutritive value (for example, leafy vegetables).	Agricultural interventions should be integrated with health and education to ensure demand for nutrient-rich varieties, which require institutional linkages. Sustainability depends on future seed availability.	Biofortification is grouped with other crop-based approaches, *integrated into a single strategy*, to increase dietary diversity and improve micronutrient intake.
Blasbalg et al., 2011 [42]	Macronutrient and micronutrient intake and status	Food fortification, provision of supplementary food– and agricultural	Based on an *econutrition* framework that links agriculture, nutrition, and ecology, undernutrition is best	Food fortification and supplementation are valuable in the short-term, and agricultural	*Econutrition* frameworks address integration of human health and

(*continued on next page*)

TABLE 4 (*continued*)

Reference	Outcome(s) discussed	Combination(s) considered	Rationale for combined strategies	Recommendations on how to combine strategies	Limitations of the article in regards to evaluating combined strategies
		food–based approaches.	solved through local, ecologically sustainable, biodiverse agriculture. Food fortification and supplementary food are important in the short-term (offering "instant impact") during the time lag for agricultural approaches, which are sustainable and offer *local food independence* to the poor.	approaches in the longer-term. Key factors for food-based strategies are discussed (for example, nutrition education, gender considerations and intrahousehold dynamics, and preparation, and storage for year-round supply).	environmental health, rather than between different food-based strategies. The article discusses features of effective agricultural approaches for nutrition, but not the integration of agrodiversity and biofortification.
Sharma et al., 2021 [44]	Micronutrient intake and status, dietary diversity, dietary quality, anemia	Nutrition-sensitive agricultural interventions, including multisectoral programs involving biofortification and homestead production.	Multisectoral programs that integrate multiple interventions have the potential to address a large number of immediate and underlying causes of undernutrition. Integration of nutrition education; water, sanitation, and hygiene; health services; gender components; micronutrient fortification; and supplementation with agricultural interventions has greater impact on the nutritional outcomes (dietary practices, anthropometry, micronutrient status, anemia).	Impact of adding intervention components beyond food production and education is heterogeneous. Need of further research on how to operationalize the right mix of intervention components in different contexts.	Examines a wide range of nutrition-sensitive agricultural interventions, identifying features and circumstances contributing to greater impact; but lacks a specific focus on micronutrient deficiency and combination of different strategies
Webb Girard et al., 2021 [37]	Vitamin A intake and status	Four case studies: all involving multiple strategies to increase intake of biofortified crop (OFSP), some with nutrition education to encourage dietary diversification/ modification	OFSP projects are important for rural areas where food fortification and supplementation have a low reach. The article's focus is on effective design of *integrated* OFSP programs (that is, agricultural inputs and training, health and nutrition education, and women's empowerment) for nutritional impact in those populations at greatest risk of vitamin A deficiency. All case study projects included nutrition education, but the extent to which this went beyond OFSP to discuss other dietary sources of vitamin A, dietary diversification, and healthy eating was not clear.	Estimating costs and benefits of integrated programs is identified to be more challenging than for direct nutrition interventions, such as supplementation. Nutrition education is the key component driving potential dietary diversification and increased intake of other vitamin A–rich foods, alongside OFSP. Recommendations are for locally-adapted education materials, clear messaging, accessible training, practical demonstrations, and sustainable delivery mechanisms.	Focus is mainly on integration of interventions within OFSP projects (to support greater intake of OFSP by target populations), not on integration with different strategies (for example, dietary diversification).

OFSP, orange fleshed sweet potato.

address many immediate and underlying causes of undernutrition, but the authors acknowledge their impact on nutritional outcomes that is not always demonstrated and further research is needed to inform the effective design of nutrition-sensitive programs in different contexts. Focusing on OFSP projects as an example of nutrition-sensitive agriculture, Webb Girard et al. [37] present four case studies from sub-Saharan Africa. This review focuses on the effective design of integrated programs, in which agricultural inputs and training are supported by nutrition education and women's empowerment. The reviewed projects are shown to have led to an increase in OFSP consumption and food diversity, but the impact on vitamin A status of mothers and children was not always significant (shown by only one case study). Webb Girard et al. [37] identify nutrition education as being essential for dietary diversification and greater intake of vitamin A–rich foods other than OFSP, and recommend integrated programs to include locally-adapted training and sustainable delivery mechanisms (for example, local health and community workers).

Discussion

Reviews included in this article [37–44] have highlighted the potential complementarity of dietary diversification and fortification and discussed their role alongside micronutrient supplementation and disease control measures. The two approaches focus on different commodities: staples for fortification and biofortification, and nutrient-rich foods such as fruits, vegetables, and animal-source foods for dietary diversification. Although dietary diversification is universally relevant, its achievement through agricultural strategies is mostly suitable to rural communities where increased production diversity has scope to enhance diets through household consumption and local markets. In such settings, access to industrially-fortified foods is likely to be constrained by distribution and limited economic resources [49]. In resource-poor settings, linear programming analyses have demonstrated that diverse diets based on local foods may be insufficient to meet requirements for some nutrients, including iron, zinc, calcium, niacin, thiamine, and folate [14–16], or that consuming nutrient-rich foods in adequate quantities will involve a substantial increase in the overall cost of the diet [50]. In such cases, food fortification is necessary to meet nutrient gaps, especially in young children [51,52]. For example, salt iodization is singled out by several authors [40,41] as the core strategy to ensure adequate intake of iodine (naturally found in a limited number of foods, notably fish and seafood for which access in inland areas is limited).

Our scoping review highlights a restricted evidence base on the impact of combining food fortification with dietary diversification. Studies evaluating a combined strategy against a control group ($n = 9$) were able to demonstrate improvements in hemoglobin status [26,27,35], micronutrient intake [24,28] and children's linear growth [23,35]. However, a limited number of studies ($n = 3$) assessed a combined strategy against a single strategy [31,33,34], hence making it difficult to ascertain whether integrated interventions had a greater impact. Beyond the dearth of studies, the complexity of integrated programs and heterogeneity of food-based approaches make it challenging to measure impact. A difficulty is that the impact observed may come from a combination of individual factors, including food-based interventions (fortification and DD) and other interventions, such as those relating to *water, sanitation, and hygiene*, and is modulated by the intensity of interventions. Evidence of impact of individual components of combined interventions is limited. Thus, studies specifically designed to evaluate multiple intervention components and their possible synergetic effect on impact should be developed. Reasons why nutrition-sensitive interventions (including biofortification and food diversification programs) can have a limited impact on a nutritional outcome and include: underlying causes of undernutrition other than food (that is, inadequate care practices and poor health status) [44]; an implementation period that is too short to achieve changes in the outcome of interest (for example, stunting) [53]; or poor study design, including a lack of statistical power and robust sampling methods, limiting the significance of findings, even where impact does exist [54]. The impact of combining interventions, involving both fortified foods and the diversification of diets, on micronutrient status remains under-researched and poorly understood. Multiplying nutrition interventions in an integrated way, targeting the same population, may lead to better outcomes than a single intervention but also poses a number of challenges. This reflects ongoing challenges in measuring impact of nutrition-sensitive interventions more broadly, as well as the paucity of studies which rigorously evaluate the multiple components of integrated food-based strategies. There is a need for well-designed and implemented studies to evaluate combined interventions: to better inform policy makers on their effectiveness, efficiency, and the method of implementation. The challenges raised by integrated food-based strategies in terms of complexity of design, of monitoring and evaluation, cost and duration should not also be underestimated.

We have conceptualized the two food-based intervention categories, and their underlying pathways in Figure 3. We can distinguish the increased intake of fortified foods and the increased intake of micronutrient-rich foods, through a diverse diet as two broad approaches by which micronutrient intake and status can be improved. Different forms of fortification, include industrial fortification, point-of-use fortification (formerly, *home fortification*), food-to-food fortification, and biofortification [55]. Food-to-food fortification [56,57] was not captured by our literature scoping review, and therefore is a limitation of our study. Although the practice of combining foods to enhance nutritional content has been practiced at a household level for centuries, it is considered a *high-potential emerging strategy* which complements existing approaches but has not been systematically described. As shown in Figure 3, both biofortification and food-to-food fortification may also contribute to the diversity of diets, as well as being forms of fortification. At a household level, food-to-food fortification might be considered equivalent to dietary diversification (for example, addition of vitamin A–rich leafy vegetables to a staple dish), whereas at an industrial level, it may be considered closer to conventional fortification (for example, the addition of milk powder to maize-soy flour blends) [57]. Similarly, biofortification has been suggested to align with a dietary diversification approach [41], as a nutrition-sensitive agricultural intervention. Food-based strategies rely on a range of determinants, such as affordability, availability, acceptability, and demand for the target foods (Figure 3). The studies included in this scoping review differed in intervention design, whereby fortification interventions typically involved a fortified food being provided to a target population, whereas dietary diversification interventions more commonly involved improving the nutritional knowledge or production diversity, but their effect on diets may be limited by economic capacity, physical availability, and intrahousehold decision-making. Nutrition-sensitive agriculture programs often promote biofortified crops alongside other micronutrient-rich foods, and nutrition education was shown to be a core component of effective interventions [58]. Webb Girard et al. [37] have argued that biofortification should be used an entry point to promote food diversity in general and improve rural people's agricultural practices, access to markets, as well as nutrition and health. Developing fortified food value chains could be a way of increasing the range of food products

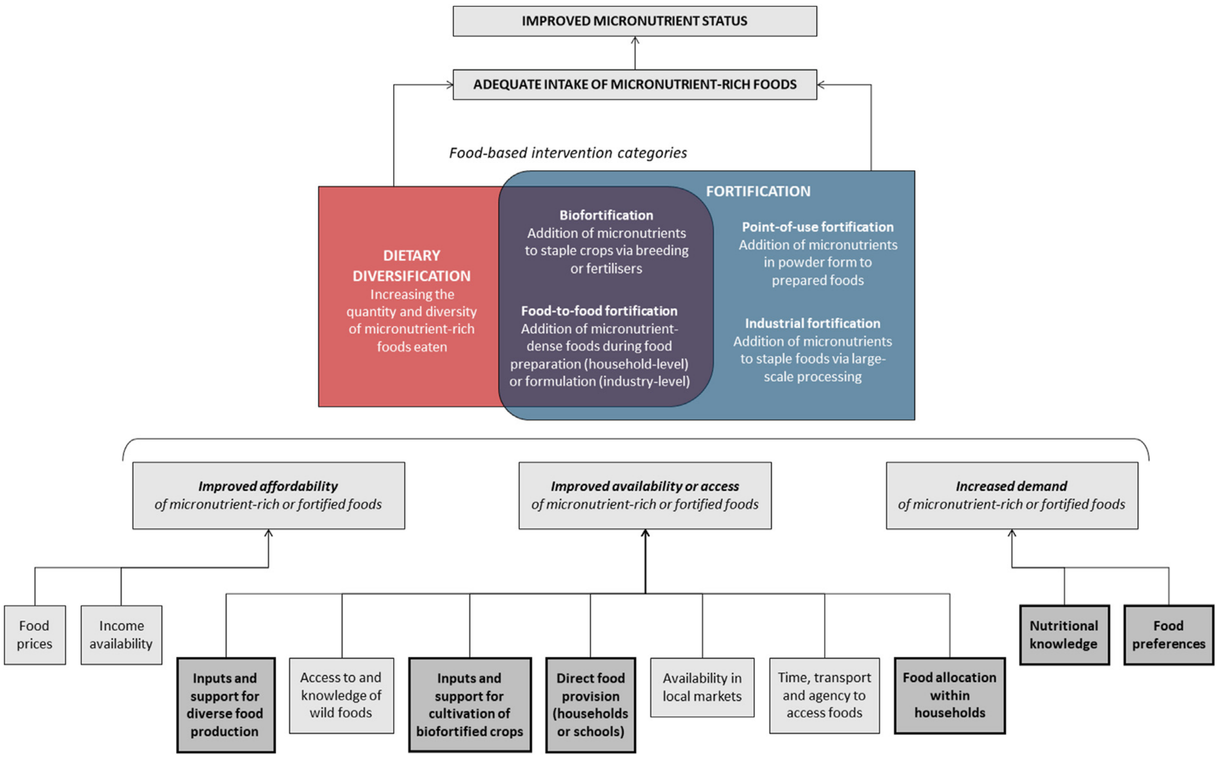

FIGURE 3. Dietary diversification and food fortification interventions as two food-based intervention strategies, and the conditions which underpin them (relating to food affordability, availability, and demand). Studies included in this review describe interventions aligned to boxes shaded in dark gray. (Source: Authors' own elaboration).

available in the markets and enhancing the diversity of food supply.

The success of any food-based strategy relies on ensuring availability, affordability, and demand for micronutrient-rich foods, particularly by vulnerable populations. For example, if biofortified foods are well accepted by consumers but rare in the market because the seed system is not well developed—or conversely, if they are widely available but nonfortified alternatives are available at low cost or more appealing to consumers—their impact on nutrition will be limited. Likewise, animal-based foods may be available, but too expensive for low-income consumers to consume on a regular basis. The prioritization of interventions should be based on strong evidence and analysis, and there is limited data around the integration of nutrition-specific and -sensitive interventions, as highlighted by a recent systematic review [59] in agreement with our findings. A tool to estimate nutrient adequacy including the cost constraints has been developed by Ferguson et al. [60], allowing the identification of limiting nutrients in the diet and this tool can be used to promote context-specific and integrated food-based interventions. A number of nutrition-sensitive interventions, including nutrition education, agricultural training (for example, farmers' field schools), school feeding programs, and cash and food transfer programs, may support both intake of fortified foods and dietary improvement. This further reinforces the relevance of a multisectoral approach, involving the agricultural and health sectors and both public and private stakeholders [61]. Public sector investment, government promotion, and a centralized seed system for the regeneration of biofortified seeds (for example, through a National Agricultural System) are essential for the sustainability of the approach [39,40]. In conclusion, our view is that integrated food-based approaches should be context specific to deliver the maximum impact on nutrition and health. All approaches to enhance the micronutrient status of populations should consider local settings, sociocultural influences, and environmental conditions. There is a need for more accurate and regular data on micronutrient deficiencies to better design integrated food-based approaches, avoid health risks from potential overlap, and a need for further research on their outcomes to inform effective interventions in diverse settings.

Author disclosures

The authors report no conflicts of interest.

Acknowledgments

This research was supported by the European Commission Food Fortification Advisory Services (2FAS) Research on Food Fortification under Lot 1 "Integrated strategies for micronutrient deficiency reduction." We thank Mohamed Mansour for reviewing this manuscript. The opinions expressed in this article do not necessarily reflect the views of our donor or partners.

Author contribution

The authors' responsibilities were as follows–AB, JdB, and AA designed the research and developed search syntax and approach to data extraction, with advice from VG and FW. AB conducted the literature search and screening of titles and abstracts. AB,

JdB, and VG conducted full-text screening. AB and JdB extracted data from primary research articles, and AA and JdB for reviews. JdB and AB developed figures with inputs from all authors. AB prepared the first draft of the manuscript and worked on subsequent drafts to produce a final manuscript. JdB and VG contributed substantively to subsequent drafts. All authors reviewed the manuscript and approved its final version.

Funding

Supported by European Commission Food Fortification Advisory Services (2FAS) Research on Food Fortification (2018–22)

Data Availability

Data described in the manuscript, code book, and analytic code will be made available upon e-mail request to the authors.

References

[1] G.A. Stevens, T. Beal, M.N.N. Mbuya, H. Luo, L.M. Neufeld, Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys, Lancet. Glob. Health. 10 (2020) e1590–e1599, https://doi.org/10.1016/S2214-109X(22)00367-9.
[2] C.G. Victora, P. Christian, L.P. Vidaletti, G. Gatica-Domínguez, P. Menon, R.E. Black, Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda, Lancet 397 (2021) 1388–1399, https://doi.org/10.1016/s0140-6736(21)00394-9.
[3] V. Greffeuille, S. Fortin, R. Gibson, F. Rohner, A. Williams, M.F. Young, et al., Associations between zinc and hemoglobin concentrations in preschool children and women of reproductive age: an analysis of representative survey data from the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) Project, J. Nutr. 151 (2021) 1277–1285, https://doi.org/10.1093/jn/nxaa444.
[4] E.N. Pearce, J.H. Lazarus, R. Moreno-Reyes, M.B. Zimmermann, Consequences of iodine deficiency and excess in pregnant women: an overview of current knowns and unknowns, Am. J. Clin. Nutr. 104 (2016) 918S–923S, https://doi.org/10.3945/ajcn.115.110429.
[5] H. Blencowe, V. Kancherla, S. Moorthie, M.W. Darlison, B. Modell, Estimates of global and regional prevalence of neural tube defects for 2015: a systematic analysis, Ann. N. Y. Acad. Sci. 1414 (2018) 31–46, https://doi.org/10.1111/nyas.13548.
[6] 2018 Global nutrition report: shining a light to spur action on nutrition, Development Initiatives, Bristol, UK, 2018.
[7] N. Petry, I. Olofin, R.F. Hurrell, E. Boy, J.P. Wirth, M. Moursi, et al., The proportion of anemia associated with iron deficiency in low, medium, and high human development index countries: a systematic analysis of national surveys, Nutrients 8 (2016) 693, https://doi.org/10.3390/nu8110693.
[8] M.T. Ruel, H. Alderman, Maternal and Child Nutrition Study Group, Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet 382 (2013) 536–551, https://doi.org/10.1016/S0140-6736(13)60843-0.
[9] Preventing micronutrient malnutrition: a guide to food-based approaches: why policy makers should give priority to food-based strategies, ILSI Press, Washington, DC, 1997.
[10] Guidelines on food fortification with micronutrients, World Health Organization and Food and Agriculture Organization of the United Nations, Geneva, Switzerland, 2006.
[11] B. Thompson, L. Amoroso, Combating micronutrient deficiencies: food-based approaches, Food and Agriculture Organization of the United Nations (FAO) and CAB International, Rome, Italy and Wallingford, UK, 2011.
[12] A.H. Kimura. 3, Solving hidden hunger with fortified food. Hidden Hunger, Cornell University Press, 2013, pp. 39–61.
[13] G. Scrinis, Reformulation, fortification and functionalization: big food corporations' nutritional engineering and marketing strategies, J Peasant Stud 43 (2016) 17–37, https://doi.org/10.1080/03066150.2015.1101455.
[14] E. Ferguson, P. Chege, J. Kimiywe, D. Wiesmann, C. Hotz, Zinc, iron and calcium are major limiting nutrients in the complementary diets of rural Kenyan children, Matern. Child. Nutr. 11 (2015) 6–20, https://doi.org/10.1111/mcn.12243.
[15] E.L. Ferguson, L. Watson, J. Berger, M. Chea, U. Chittchang, U. Fahmida, et al., Realistic food-based approaches alone may not ensure dietary adequacy for women and young children in South-East Asia, Matern. Child. Health. J. 23 (2019) 55–66, https://doi.org/10.1007/s10995-018-2638-3.
[16] R.S. Gibson, K.B. Bailey, M. Gibbs, E.L. Ferguson, A review of phytate, iron, zinc, and calcium concentrations in plant-based complementary foods used in low-income countries and implications for bioavailability, Food Nutr. Bull. 31 (2010) S134–S146, https://doi.org/10.1177/15648265100312S206.
[17] M. Qaim, K.T. Sibhatu, On the link between production diversity and dietary quality in smallholder farm households, World. Rev. Nutr. Diet. 118 (2017) 102–111, https://doi.org/10.1159/000484510.
[18] K.T. Sibhatu, V.V. Krishna, M. Qaim, Production diversity and dietary diversity in smallholder farm households, Proc. Natl. Acad. Sci. U. S. A. 112 (2015) 10657–10662, https://doi.org/10.1073/pnas.1510982112.
[19] M. Campos Ponce, K. Polman, N. Roos, F.T. Wieringa, J. Berger, C.M. Doak, What approaches are most effective at addressing micronutrient deficiency in children 0-5 years? A review of systematic reviews, Matern. Child Health J. 23 (2019) 4–17, https://doi.org/10.1007/s10995-018-2527-9.
[20] A.C. Tricco, E. Lillie, W. Zarin, K.K. O'Brien, H. Colquhoun, D. Levac, et al., PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation, Ann. Intern. Med. 169 (2018) 467–473, https://doi.org/10.7326/M18-0850.
[21] M.D.J. Peters, C. Marnie, A.C. Tricco, D. Pollock, Z. Munn, L. Alexander, et al., Updated methodological guidance for the conduct of scoping reviews, J.B.I. Evid. Synth. 18 (2020) 2119–2126, https://doi.org/10.11124/JBIES-20-00167.
[22] S.P. Walker, T.D. Wachs, J.M. Gardner, B. Lozoff, G.A. Wasserman, E. Pollitt, et al., Child development: risk factors for adverse outcomes in developing countries, Lancet 369 (2007) 145–157, https://doi.org/10.1016/S0140-6736(07)60076-2.
[23] H.B. Lanou, S.J.M. Osendarp, A. Argaw, K. De Polnay, C. Ouédraogo, S. Kouanda, et al., Micronutrient powder supplements combined with nutrition education marginally improve growth amongst children aged 6-23 months in rural Burkina Faso: A cluster randomized controlled trial, Matern. Child Nutr. 15 (2019), e12820, https://doi.org/10.1111/mcn.12820.
[24] J.L. Leroy, D. K Olney, L. Bliznashka, M. Ruel, Tubaramure, A food-assisted maternal and child health and nutrition program in Burundi, increased household food security and energy and micronutrient consumption, and maternal and child dietary diversity: a cluster-randomized controlled trial, J. Nutr. 150 (2020) 945–957, https://doi.org/10.1093/jn/nxz295.
[25] Z. Abebe, E. Gebeye, A. Tariku, Poor dietary diversity, wealth status and use of un-iodized salt are associated with goiter among school children: a cross-sectional study in Ethiopia, B.M.C. Public Health. 17 (2017) 44, https://doi.org/10.1186/s12889-016-3914-z.
[26] L.M. Locks, I. Reerink, A.M. Brown, S. Gnegne, N. Ramalanjaona, S. Nanama, et al., The impact of integrated infant and young child feeding and micronutrient powder intervention on feeding practices and anemia in children aged 6-23 months in Madagascar, Nutrients 9 (2017) 581, https://doi.org/10.3390/nu9060581.
[27] A.A. Kalimbira, C. Macdonald, J.R. Randall Simpson, The impact of an integrated community-based micronutrient and health programme on anaemia in non-pregnant Malawian women, Public. Health. Nutr. 13 (2010) 1445–1452, https://doi.org/10.1017/S1368980009991820.
[28] C. Hotz, C. Loechl, A. de Brauw, P. Eozenou, D. Gilligan, M. Moursi, et al., A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women, Br. J. Nutr. 108 (2012) 163–176, https://doi.org/10.1017/S0007114511005174.
[29] C. Hotz, C. Loechl, A. Lubowa, J.K. Tumwine, G. Ndeezi, A. Nandutu Masawi, et al., Introduction of β-carotene–rich orange sweet potato in rural Uganda resulted in increased vitamin A intakes among children and women and improved vitamin A status among children,

J. Nutr. 142 (2012) 1871–1880, https://doi.org/10.3945/jn.111.151829.
[30] S.A. Tanumihardjo, B.M. Gannon, C. Kaliwile, J. Chileshe, Hypercarotenodermia in Zambia: which children turned orange during mango season? Eur. J. Clin. Nutr. 69 (2015) 1346–1349, https://doi.org/10.1038/ejcn.2015.143.
[31] R.K. Campbell, K.M. Hurley, A.A. Shamim, S. Shaikh, Z.T. Chowdhury, S. Mehra, et al., Complementary food supplements increase dietary nutrient adequacy and do not replace home food consumption in children 6-18 months old in a randomized controlled trial in rural Bangladesh, J. Nutr. 148 (2018) 1484–1492, https://doi.org/10.1093/jn/nxy136.
[32] A. Diana, S.R. Mallard, J.J. Haszard, D.M. Purnamasari, I. Nurulazmi, P.D. Herliani, et al., Consumption of fortified infant foods reduces dietary diversity but has a positive effect on subsequent growth in infants from Sumedang district, Indonesia, PLOS ONE 12 (2017), e0175952, https://doi.org/10.1371/journal.pone.0175952.
[33] A.K. Osei, P. Pandey, D. Spiro, D. Adhikari, N. Haselow, C. De Morais, et al., Adding multiple micronutrient powders to a homestead food production programme yields marginally significant benefit on anaemia reduction among young children in Nepal, Matern. Child Nutr. 11 (2015) 188–202, https://doi.org/10.1111/mcn.12173.
[34] I. Angeles-Agdeppa, E. Monville-Oro, J.F. Gonsalves, M.V. Capanzana, Integrated school based nutrition programme improved the knowledge of mother and schoolchildren, Matern. Child Nutr. 15 (2019), e12794, https://doi.org/10.1111/mcn.12794.
[35] J.A. Rivera, D. Sotres-Alvarez, J.P. Habicht, T. Shamah, S. Villalpando, Impact of the Mexican program for education, health, and nutrition (Progresa) on rates of growth and anemia in infants and young children: a randomized effectiveness study, JAMA 291 (2004) 2563–2570, https://doi.org/10.1001/jama.291.21.2563.
[36] S.A. Tanumihardjo, N. Mokhtar, M.J. Haskell, K.H. Brown, Assessing the safety of vitamin A delivered through large-scale intervention programs: workshop report on setting the research agenda, Food Nutr. Bull. 37 (2016) S63–S74, https://doi.org/10.1177/0379572116630480.
[37] A.W. Girard, A. Brouwer, E. Faerber, F.K. Grant, J.W. Low, Orange-fleshed sweetpotato: strategies and lessons learned for achieving food security and health at scale in Sub-Saharan Africa, Open Agric 6 (2021) 511–536, https://doi.org/10.1515/opag-2021-0034.
[38] R.J. Hillocks, Farming for balanced nutrition: an agricultural approach to addressing micronutrient deficiency among the vulnerable poor in Africa, Afr. J. Food Agric. Nutr. Dev. 11 (2011) 4688–4707, https://doi.org/10.4314/ajfand.v11i2.65922.
[39] T. Johns, P.B. Eyzaguirre, Biofortification, biodiversity and diet: a search for complementary applications against poverty and malnutrition, Food Policy 32 (2007) 1–24, https://doi.org/10.1016/j.foodpol.2006.03.014.
[40] L.H. Allen, To what extent can food-based approaches improve micronutrient status? Asia Pac. J. Clin. Nutr. 17 (2008) 103–105.
[41] E. Boy, V. Mannar, C. Pandav, B. de Benoist, F. Viteri, O. Fontaine, et al., Achievements, challenges, and promising new approaches in vitamin and mineral deficiency control, Nutr. Rev. 67 (2009) S24–30, https://doi.org/10.1111/j.1753-4887.2009.00155.x.
[42] T.L. Blasbalg, B. Wispelwey, R.J. Deckelbaum, Econutrition and utilization of food-based approaches for nutritional health, Food Nutr. Bull. 32 (2011) S4–S13, https://doi.org/10.1177/15648265110321S102.
[43] R.S. Gibson, Zinc deficiency and human health: etiology, health consequences, and future solutions, Plant. Soil. 361 (2012) 291–299, https://doi.org/10.1007/s11104-012-1209-4.
[44] I.K. Sharma, S. Di Prima, D. Essink, J.E.W. Broerse, Nutrition-sensitive agriculture: a systematic review of impact pathways to nutrition outcomes, Adv. Nutr. 12 (2021) 251–275, https://doi.org/10.1093/advances/nmaa103.
[45] A. de Brauw, M. Moursi, A.B. Munhaua, Vitamin A intakes remain higher among intervention participants 3 years after a biofortification intervention in Mozambique, Br. J. Nutr. 122 (2019) 1175–1181, https://doi.org/10.1017/S0007114519002162.
[46] K.M. Jones, A. de Brauw, Using agriculture to improve child health: promoting orange sweet potatoes reduces diarrhea, World Dev 74 (2015) 15–24, https://doi.org/10.1016/j.worlddev.2015.04.007.
[47] M. Dass, J. Nyako, C. Tortoe, N. Fanou-Fogny, E. Nago, J. Hounhouigan, et al., Comparison of micronutrient intervention strategies in Ghana and Benin to cover micronutrient needs: simulation of bene-fits and risks in women of reproductive age, Nutrients 13 (2021) 2286, https://doi.org/10.3390/nu13072286.
[48] S.A. Tanumihardjo, C. Kaliwile, E. Boy, M.A. Dhansay, M.E. van Stuijvenberg, Overlapping vitamin A interventions in the United States, Guatemala, Zambia, and South Africa: case studies, Ann. N. Y. Acad. Sci. 1446 (2019) 102–116, https://doi.org/10.1111/nyas.13965.
[49] K. Tang, K.P. Adams, E.L. Ferguson, M. Woldt, A.A. Kalimbira, B. Likoswe, et al., Modeling food fortification contributions to micronutrient requirements in Malawi using household consumption and expenditure surveys, Ann. N. Y. Acad. Sci. 1508 (2022) 105–122, https://doi.org/10.1111/nyas.14697.
[50] J. Raymond, N. Kassim, J.W. Rose, M. Agaba, Optimal formulations of local foods to achieve nutritional adequacy for 6-23-month-old rural Tanzanian children, Food Nutr. Res. 61 (2017), 1358035, https://doi.org/10.1080/16546628.2017.1358035.
[51] U. Fahmida, O. Santika, R. Kolopaking, E. Ferguson, Complementary feeding recommendations based on locally available foods in Indonesia, Food Nutr. Bull. 35 (2014) S174–S179, https://doi.org/10.1177/15648265140354S302.
[52] L.M. Hlaing, U. Fahmida, M.K. Htet, B. Utomo, A. Firmansyah, E.L. Ferguson, Local food-based complementary feeding recommendations developed by the linear programming approach to improve the intake of problem nutrients among 12–23-month-old Myanmar children, Br. J. Nutr. 116 (2016) S16–S26, https://doi.org/10.1017/S000711451500481X.
[53] A. Herforth, T.J. Ballard, Nutrition indicators in agriculture projects: current measurement, priorities, and gaps, Glob. Food Sec. 10 (2016) 1–10, https://doi.org/10.1016/j.gfs.2016.07.004.
[54] P. Webb, E. Kennedy, Impacts of agriculture on nutrition: nature of the evidence and research gaps, Food Nutr. Bull. 35 (2014) 126–132, https://doi.org/10.1177/156482651403500113.
[55] R. Olson, B. Gavin-Smith, C. Ferraboschi, K. Kraemer, Food fortification: the advantages, disadvantages and lessons from sight and life programs, Nutrients 13 (2021) 1118, https://doi.org/10.3390/nu13041118.
[56] F.J. Chadare, R. Idohou, E. Nago, M. Affonfere, J. Agossadou, T.K. Fassinou, et al., Conventional and food-to-food fortification: an appraisal of past practices and lessons learned, Food Sci. Nutr. 7 (2019) 2781–2795, https://doi.org/10.1002/fsn3.1133.
[57] J. Kruger, J.R.N. Taylor, M.G. Ferruzzi, H. Debelo, What is food-to-food fortification? A working definition and framework for evaluation of efficiency and implementation of best practices, Compr. Rev. Food Sci. Food Saf. 19 (2020) 3618–3658, https://doi.org/10.1111/1541-4337.12624.
[58] J.W. Low, G. Thiele, Understanding innovation: the development and scaling of orange-fleshed sweetpotato in major African food systems, Agric. Syst. 179 (2020), 102770, https://doi.org/10.1016/j.agsy.2019.102770.
[59] L.H. Abdullahi, G.K. Rithaa, B. Muthomi, F. Kyallo, C. Ngina, M.A. Hassan, et al., Best practices and opportunities for integrating nutrition specific into nutrition sensitive interventions in fragile contexts: a systematic review, B.M.C. Nutr. 7 (2021) 46, https://doi.org/10.1186/s40795-021-00443-1.
[60] M. Maillot, E.L. Ferguson, A. Drewnowski, N. Darmon, Nutrient profiling can help identify foods of good nutritional quality for their price: a validation study with linear programming, J. Nutr. 138 (2008) 1107–1113, https://doi.org/10.1093/jn/138.6.1107.
[61] B. Lalani, A. Bechoff, B. Bennett, Which choice of delivery model(s) works best to deliver fortified foods? Nutrients 11 (2019) https://doi.org/10.3390/nu11071594.