Synthesis of Evidence, Knowledge Gaps, and Priorities for Food-Based and Home-Fortification Interventions

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on the

Micronutrient Quality of Complementary Feeding in Early Childhood

Micronutrient FORUM

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Overview

While exclusive breastfeeding in the first 6 months of life is best for babies everywhere, they should be given nutritious complementary foods from 6 months onward with continued breastfeeding up to the age of two years or beyond. The micronutrient quality of complementary feeding for children 6–23 months is a critical driver of malnutrition in early childhood. The impact of a poor-quality diet in the first two years of life endures beyond this critical period, as insufficient micronutrient intake can irreversibly affect a child's developing brain and body and can limit future learning, health, and well-being. Yet, despite global development and increasing evidence that poor diets of young children impact their future, most children are not consuming even the minimum diet needed to survive and reach their potential.

UNICEF's *Fed to Fail* report highlights the most prominent barriers to good diets for young children (UNICEF 2021). The analyses drew on the UNICEF Global Database on Infant and Young Child Feeding, comprising data from 607 nationally representative surveys conducted in 135 countries and territories and representing more than 90% of all children under 2 years of age globally. These findings showed that children are not fed sufficient quantities of the right foods at the right time to meet their micronutrient needs. Stunting increases rapidly between 6 and 23 months of age, and more than half of all children with wasting are younger than 2 years of age. The diets of young children are failing with respect to timeliness, frequency, and diversity. Currently, only 73% of children aged 6–8 months are fed any solid foods. Among children aged 6–23 months, only 52% are fed with the minimum meal frequency[1] and only 29% benefit from minimally diverse diets.[2] Nearly half of these children across the global survey were shown to be missing the lifelong benefits of the most nutrient-rich foods, such as fruits and vegetables (41% did not consume these foods during the previous day) and eggs, fish, and meat (55% did not consume egg and/or flesh food the previous day). Furthermore, children's diets have seen little or no improvement in the past decade. Gaps in knowledge remain on what is needed at the household, community, service delivery, and policy levels to improve the micronutrient quality of children in the complementary feeding age.

Several global initiatives are underway to accelerate action toward improving the quality of complementary feeding. The World Health Organization (WHO) is developing guidelines on complementary feeding to be published toward the end of 2023. UNICEF is working on the development of implementation guidance on complementary feeding jointly with the WHO, on the Complementary Feeding in Emergencies Action Plan, and on documenting complementary feeding in emergency interventions. UNICEF is also in the process of establishing a Global Collective on Complementary Feeding later in 2023.

In light of the *Fed to Fail* findings, UNICEF calls for bolder actions and greater accountability for children's diets. It recommends 10 actions:

1. Increase the availability and affordability of nutritious foods by incentivizing their production, distribution, and retailing.
2. Implement national standards and legislation to protect young children from unhealthy foods and harmful marketing.

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[1] Minimum meal frequency is defined as the percentage of children aged 6–23 months who consumed solid, semi-solid, or soft foods (but also including milk feeds for non-breastfed children) the minimum number of times or more during the previous day.

[2] Minimum dietary diversity is defined as the percentage of children aged 6–23 months who consumed foods and beverages from at least five out of eight defined food groups during the previous day.

3. Use multiple communication channels to reach caregivers and increase the desirability of nutritious foods.
4. Expand caregivers' access to counseling and support on young child feeding by investing in community counselors and health workers.
5. Deliver dietary supplements, home fortificants, and fortified complementary foods to children at risk.
6. Design social transfers (cash, food, or vouchers) to support nutritious and healthy diets, including in emergencies.
7. Use social protection to increase caregivers' knowledge of young child feeding.
8. Position young children's diets as a priority in the national development agenda.
9. Strengthen public accountability by setting targets and tracking progress.
10. Conduct research to understand context-specific barriers, enablers, and pathways to improving the quality of young children's diets.

This background document aims to synthesize some of the key evidence on food-based and home-fortification interventions, both of which needed to improve the micronutrient quality of the complementary diet. The overarching issue in this review relates to the child nutrition and health outcomes of complementary feeding. The types of child nutrition and health outcomes cited in the literature range from functional outcomes (e.g., cognitive development, linear growth) to ultimate outcomes (e.g., morbidity and mortality) as well as intermediate outcomes (e.g., filling the nutrient gaps in the complementary diet to meet intake recommendations) and longer-term outcomes such as taste development that affects later food consumption patterns. Evidence that references specific outcomes is cited as in the literature, whereas use of the term "child nutrition and health outcomes" refers broadly to the range of outcomes of complementary feeding.

The interventions reviewed in this synthesis include a combination of food-based approaches—specifically animal-source foods (eggs, fish, meat), nuts and legumes, and fruits and vegetables—and home fortification products—including micronutrient powders (MNPs), small-quantity lipid-based nutrient supplements (SQ-LNS), dried egg powder, and dried fish powder. Rigorous large-scale program evaluations have identified critical factors for improving complementary feeding in several contexts. However, analogous adoption by countries will require more work on filling evidence and implementation knowledge gaps, costing, budgeting, and financing (Menon et al. 2016; Kim et al. 2019; Rawat et al. 2017). This review also highlights the main barriers and enablers—related to availability, accessibility, affordability, feasibility, acceptability, caregiver time, and household dynamics—that prevent or enable young children to consume nutritious, safe, micronutrient-rich diets. For instances in which food-specific barriers are not listed, they were not readily identified in the high-level literature search.

This synthesis is intended not as a systematic or comprehensive review but rather as a summary of key evidence and a shared context from which to collectively identify, inform, and align research and program gaps and priorities for improving the micronutrient quality of the complementary diet globally. Several potential foods or interventions during the complementary feeding period have not been included in this summary. Continued breastfeeding is well established as an essential child feeding practice for young children 6–23 months old and is the subject of many child feeding studies and interventions. As such, breast milk and breastfeeding are not included in this evidence summary. Commercially available, fortified complementary foods have not been included as some of the barriers are vastly different than those for food-based and home-fortification interventions. Differences include issues related to accessibility, marketing, and composition—notably the risk of high energy, sugar, sodium, and saturated fat content. Similarly, as unhealthy ultraprocessed foods are being given to children in the complementary feeding period, displacing healthy, nutrient-rich foods, it was felt that the use of ultraprocessed foods, both healthy and unhealthy, is a large area on its own. This synthesis also does not review the effectiveness of social behavioral change communication approaches used to enhance adoption of complementary feeding recommendations, though the topic is extremely relevant.

Evidence Base and Barriers for Food-Based and Home-Fortification Interventions

For the food-based interventions, Table 1 summarizes the micronutrient density scores for key nutrients for children aged 6–23 months (Ortenzi and Beal 2021). Foods were classified into one of four levels of micronutrient density based on the calories and grams needed to provide one-third of recommended intakes of vitamin A, folate, vitamin B12, calcium, iron, and zinc.[3]

Table 1. Summary of priority foods micronutrient density scores for children aged 6–23 months

Source	2+ micronutrients	Iron	Zinc	Vitamin A	Calcium	Folate	Vitamin B12
Eggs/egg powder	Very high	Low	Very high	Very high	Low	High	Very high
Fish/fish powder	Very high	Very high	Very high	Low	Low	Low	Very high
Meat – liver/spleen	Very high	Very high	Very high	Very high	Low	Very high	Very high
Meat-beef	High	High	Very high	Low	Low	Low	Very high
Meat-pork	Low	Low	High	Low	Low	Low	Moderate
Meat-chicken	Low	Low	Moderate	Low	Low	Low	Moderate
Vitamin A-rich fruits and vegetables	Low	Low	Low	Very high	Low	Low	Low
Other vegetables	Low	Low	Low	Low	Low	Low	Low
Nuts	Low	Low	Low	Low	Low	Low	Low
Seeds	Low	Low	High	Low	Low	High	Low
Legumes	Low	Moderate	Low	Low	Low	Very high	Low

Source: Adapted from Ortenzi and Beal (2021).

Animal-source foods

Animal-source foods provide critical nutrients for the young child diet. The 2003 WHO Guiding Principles for Complementary Feeding recommend including meat, poultry, fish, or eggs as often as possible in the diets of young children as they provide essential nutrients in highly bioavailable forms (WHO 2012). Conditions for improving the availability, access, and consumption of animal-source foods often vary across subnational regions, and agricultural and economic databases combined with food consumption data can be used to help identify the priority areas for program adoption. Ongoing updates capture shifts in influencing factors (Hirvonen and Wolle 2018).

[3] For the aggregate score, the average share of recommended intakes across the six micronutrients, for a given quantity of calories and grams of a given food was calculated according to the following thresholds for average requirements (ARs) of energy and hypothetical ARs for mass, assuming an energy density of 1.3kcal/g (the mean energy density of a minimally processed, plant-based, low-fat diet and an animal-based, ketogenic diet):

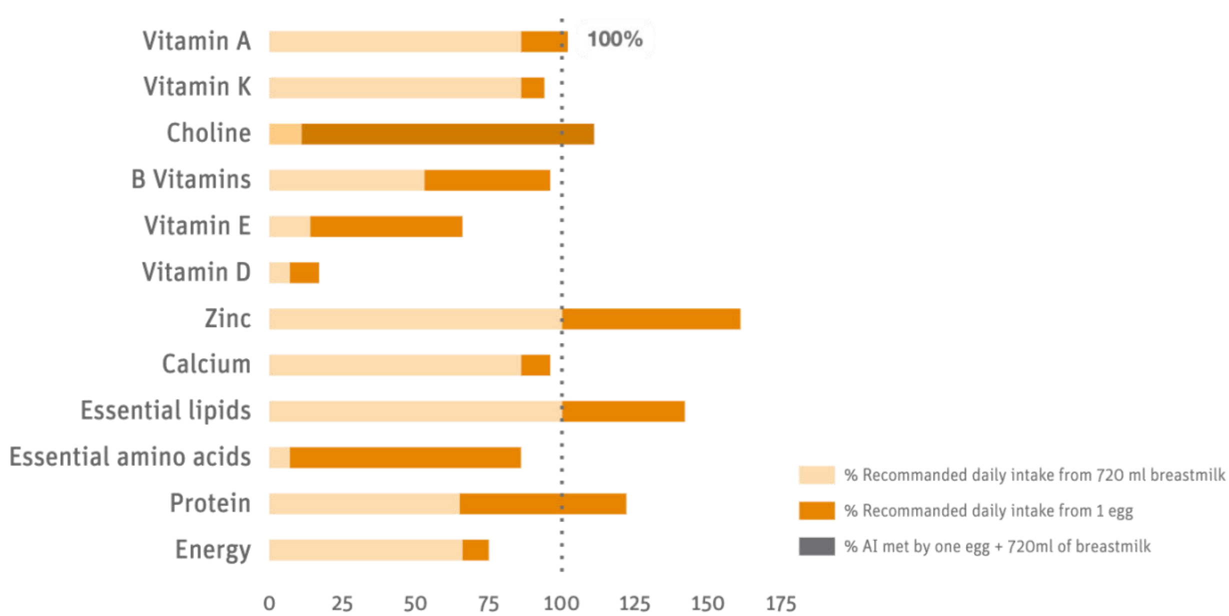
- Very high: ≤ one-sixth of ARs for both energy and mass
- High: ≤ one-third of ARs for both energy and mass and < one-sixth of ARs for either energy or mass
- Moderate: ≤ one-third and > one-sixth of ARs for both energy and mass
- Low: > one-third of ARs for either energy or mass

Eggs

Eggs possess high nutrient density for protein (6 grams for a single hen egg), lipids, and micronutrients, including vitamins A, D, E, K, B1, B2, B5, B6, B9, and B12 in the yolk, and high quantities of vitamins B2, B3, and B5 in the white. Eggs contain a dense concentration of choline (critical for brain development), with one medium egg yolk providing 98% of the adequate intake for children aged 7–12 months. They also provide more than 50% of the adequate intake of protein, selenium, vitamin B12, potassium, and riboflavin, and between 25% and 50% of the adequate intake of energy, pantothenic acid, vitamin B6, folate, phosphorus, and zinc (Iannnotti et al. 2014a). Eggs contain no fiber and very low carbohydrate content (0.7%).

The egg yolk contains iron (2.73mg/100g) (Réhault-Godbert et al. 2019), though the potential impact of eggs on iron status is unclear. One chicken egg contains 0.9 mg of non-heme iron (8% of the recommended daily allowance for infants 6–12 months old or 13% for children 12–24 months). The iron content has limited bioavailability because it is tightly bound to phosvitin, which is not readily degraded by proteolytic enzyme digestion (Werner et al. 2022a). Moreover, whole eggs and egg whites inhibit iron bioavailability, reducing dietary absorption. Nevertheless, at least one study has shown some potential for eggs to increase iron status among infants (Makrides et al. 2002). Despite this uncertainty, recent evidence showed that for infants aged 9–11 months, consuming one egg (60 grams) in addition to the recommended daily intake of breast milk (720 milliliters) can help the infant get nearly 100% of the daily recommended requirement of most nutrients (Figure 1) (Sight and Life 2023a).

Figure 1. Nutritional needs met by daily intake of 1 egg and 720 ml breast milk for infants 9–11 months



Source: Sight and Life (2023a).

Despite the high nutrient density of eggs, the evidence to date of the impact of egg consumption during the early complementary phase on child growth and nutrition outcomes has been inconclusive. Numerous trials have been conducted in which children were provided one egg per day during the early complementary feeding period, with mixed results on dietary diversity, growth, and stunting outcomes. Together, the evidence to date largely suggests that eggs as a food-based intervention can improve complementary feeding dietary diversity in young children during a critical period in their development; however, the translation to improvements in linear growth or other functional outcomes is still uncertain.

Summary of Select Egg Intervention Trial Evidence

The Lulun Project, a six-month egg intervention early in the complementary feeding period in the Ecuadorian Andes, resulted in 47% reduction in the prevalence of stunting, a significant increase in length-for-age z score (LAZ) of 0.63, and an increase in biomarkers associated with cognitive development (Iannotti et al. 2017). The results suggested that eggs in the complementary diet may be an opportunity to improve early childhood growth. However, given the small sample size, it was unknown whether results would be broadly generalizable. A follow-up cohort study in Ecuador (Lulun Project II) found that growth effects of the egg intervention during the early complementary feeding period were no longer evident two years later; however, continued egg consumption was associated with reduced growth faltering in the two-year period, suggesting that eggs continued to be associated with smaller post-intervention declines (Iannotti et al. 2020).

The replication of the Ecuador study design in Malawi, the Mazira Project, found provision of one egg per day for six months produced no improvement in length or risk of stunting, though there was some benefit on LAZ among children of highly educated mothers (Stewart et al. 2019). In another Malawi study, one egg per day for children 6–9 months old dramatically increased egg consumption (from 3.9% at baseline to 85.5% at three months). As a result, 80% of children in the egg group consumed a minimally diverse diet compared with 60% in the control group. Despite these significant improvements in diet quality, the intervention did not result in improvements in linear growth or stunting reduction (Stewart et al. 2019). Contextual differences between Ecuador and Malawi and baseline stunting rates as well as common consumption of fish in Malawi may have limited the potential for children in Malawi to benefit from egg consumption.

These two studies illustrate the value of replication. One egg per day over six months improved short-term growth among young children in Ecuador but not in Malawi. Micronutrient intake inadequacies were high in Malawi and remained high even in the intervention group. While fish consumption was common, portion sizes were very small (<5g/day). Plasma choline and DHA explained some of the growth effect in Ecuador. Choline intake was far below requirements in Malawi in the control group. It was improved with eggs but still inadequate, and it was not enough to change plasma choline. A high burden of infection and inflammation in Malawi may have limited the potential to respond to the dietary intervention. Effects thus may be context-specific with variation due to the potential to benefit and the potential to respond.

Similar improvements in dietary diversity were achieved in a complementary feeding egg trial in South Africa (Faber et al. 2022). In a recent Bangladesh trial, provision of eggs for infants aged 6–12 months improved dietary intakes but was insufficient to meet recommendations for intake of multiple micronutrients, highlighting the need for egg interventions to be coupled with other strategies (Pasqualino et al. 2023). Another study underway is the Saqmolo' Project in Guatemala, which is evaluating the influence of adding one egg per day to standard local nutrition care for six months on child development, growth, and dietary quality in Mayan infants aged 6–9 months at baseline (Wallace et al. 2022).

Multisectoral interventions that provided inputs other than food demonstrate an effect on child egg consumption and growth. In Ethiopia, a behavior change intervention delivered through interpersonal communication, agricultural activities, community mobilization, and mass media showed a strong *association between the agricultural activities and egg consumption, which resulted in increased child dietary diversity and linear growth (Kim et al. 2016). In Ghana, a package of inputs and training in poultry farming and home gardening and education in nutrition and care resulted in increases in child dietary diversity and egg consumption and improvements in linear growth in the intervention group compared with controls (Marquis et al. 2018). In contrast, in Bangladesh, a behavior change intervention that did not provide food or other inputs resulted in large improvements in complementary feeding diets, including egg consumption, but no increases in linear growth (Menon et al. 2016).*

Although in recent year global egg production has been estimated at nearly one egg a day for every two humans (FAO 2017), consumption of eggs in the complementary period is relatively low in contexts of poverty (Lutter et al. 2018), indicating that important barriers to implementation exist.

Availability

Average per capita availability for high-income countries is 265 eggs per year, roughly six to eight times more than in low- and middle-income countries (LMICs). In many low-resource contexts, eggs are produced in quantities only sufficient to provide each inhabitant with a few eggs each month (e.g., availability of eggs per capita per year is 9 in Ethiopia, 27 in Malawi, 46 in Kenya, and 60 in India) (FAO 2013; Beesabathuni et al. 2018). Long-distance transportation of shell eggs is generally not possible owing to the fragile and perishable nature of the product as well as the increased risk of potential pathogen contamination (Morris et al. 2018; Iannotti et al. 2014a). Additionally, this gap in availability in low-resource settings is due to other challenges along the egg value chain, including the predominance of backyard poultry marked by frequent disease outbreaks and limited financing, the limited role of the private sector in the egg value chain, high feed prices, low biosecurity for business models that result in disease outbreaks, and diseases caused by infection of avian influenza type A viruses that can evolve into highly pathogenic viruses and production losses (Sight and Life 2023b).

Affordability

While eggs are considered relatively more affordable for low-resource households than other animal-source foods (Iannotti et al. 2014a; Faber et al. 2022)—for instance, eggs are considered one of the cheapest animal protein sources available in South Africa (Nkukwana 2018)—their cost is prohibitive for many LMIC households and considered the primary barrier to uptake (Lutter et al. 2021; Headey and Alderman 2019; Menon et al. 2016; Makrides et al. 2002). The high price of eggs relative to incomes is, at least in part, a reflection of weak market integration, the seasonality of demand, and the high transaction cost (e.g., breakage of eggs). Across the world, eggs are expensive relative to staple cereal crops. The high cost of eggs is also a direct result of the dominant production system; extensive poultry rearing is inefficient and low yield and associated with high egg prices and low consumption.

Feasibility

Raising the productivity of individual small-scale producers is unlikely to significantly improve egg consumption at a national level, according to modeled scenarios of pathways to affordable egg access. However, an egg hub model of medium-scale producers has been suggested to increase access for many poor contexts, while large-scale intensive production is likely needed to meet the needs of urban populations (Morris et al. 2018). Other research has suggested that smallholder business models and production centers can increase egg availability and children's egg consumption (Beesabathuni et al. 2018; Dumas et al. 2018).

Safety

Food safety is another concern for egg interventions. Eggs can easily be contaminated with pathogens, and the production of eggs in households or by small-scale producers poses hygiene challenges and thus increases risk of disease, particularly for young children. Shell eggs are susceptible to microbial spoilage and carry a risk of salmonella, so using egg powder, made by drying eggs that have been homogenized and pasteurized, provides the advantage of reducing the risk of salmonella transmission (Moore et al. 1988).

Acceptability

Eggs are widely acceptable to most populations. They are also versatile in their preparation and can be well integrated into many traditional diets. Cultural avoidance of egg consumption is important in some places (notably northern and western India, where vegetarianism is valued and the domestic chicken is considered an unclean animal; Simoons 1994) and for select subgroups of the general population, including children under two years of age. Studies show, however, that well-informed and carefully conducted social marketing and behavior change communication can likely overcome cultural barriers and egg taboos (Gallegos-Riofrio et al. 2018). Designating a portion of home-produced eggs specifically for child consumption, as part of intensive social behavior change interventions delivered through multiple platforms led to significant improvements in complementary feeding practices and child stunting within a 2-y period. (Kim et al. 2019).

Egg Powder

Egg powder, made from spray-dried eggs, has the advantage of manufacturability, storability, and easy addition to complementary foods. It is less susceptible to microbial spoilage and carry a lower risk of salmonella (Moore et al. 1988). Drying reduces both weight and volume, concentrating nutrients and thus increasing eggs' potential as nutritional supplements for vulnerable populations (Mittermeier-Kleßinger et al. 2021).

Recent research shows that egg powder retains most of the high nutritional quality of pasteurized whole eggs without accumulating potentially harmful compounds. A daily intake of spray-dried egg powder corresponding to one medium-sized egg meets dietary reference values for children for several micronutrients (e.g., 100% for vitamin E, 24% for retinol, 61% for selenium, and 22% for zinc). Recent results demonstrate a high potential for spray-dried eggs as a nutritional supplement. However, the spray-drying process could be optimized toward higher retentions of unsaturated fatty acids and retinol (Pirkwieser et al. 2022; Bimbo et al. 2017).

Barriers to consumption of egg powder include current limited availability and unknown acceptability among many subpopulations. To date, however, few studies have examined the enablers and barriers to uptake, outside of cost and affordability.

Affordability

While drying eggs into powder has an inherent cost, the expense of production is outweighed by the reduced transport and storage costs, the increased shelf life, and the easier use of smaller portions—factors that ultimately increase the affordability of egg consumption. Using the Cost of the Diet analysis, researchers evaluated the incorporation of egg powder into children's diets in Ethiopia for its contribution to the nutrient adequacy and affordability of diets. The minimum-cost nutritious diet required only 2.5 g of egg powder per person per day to reduce the cost of the optimized diet by 14% (0–24%). This would allow an additional 1.2 million households (about 4–6 million individuals) to afford the optimized diet—a number equal to all households with a child 6–23 months of age in the top four wealth quintiles. Free distribution of egg powder to households in the poorest wealth quintile, if supplemented by effective nutrition education, could allow them to afford the minimum-cost nutritious diet for their 6- to 23-month-old child. This evidence suggests that the simple dehydration of egg into egg powder can make a substantial contribution toward increased egg consumption by increasing the affordability of the minimum-cost nutritious diet (Baye et al. 2021).

Fish and Aquatic Foods

The global agenda on aquatic foods has grown. The UN Nutrition discussion paper (2021) included evidence and recommendations on the importance of aquatic foods in improving global food and nutrition security. Fish contain high concentrations of several minerals, vitamins, polyunsaturated fatty-acids, and micronutrients that are critical for proper growth and development—notably iron, vitamin A, calcium, iodine, zinc, selenium, omega-3 long-chain fatty acids, and vitamin B12 (Kawarazuka and Béné 2011). Fish increases absorption of plant-based micronutrients, which is particularly beneficial in populations where cereal-based staples make up the majority of the diet (Aung-Than-Batu et al. 1976; Gibson and Hotz 2001; Michaelsen et al. 2009). Recent studies suggest that children who consume higher levels of fish are more likely to meet daily nutritional requirements and have better growth outcomes than those who do not (Gibson et al. 2020; Marinda et al. 2018).

In some geographic contexts, small fish are the primary flesh food intake for young children and have been shown to impact nutrition outcomes. For example, increases in small fish consumption by young Malawian children was shown to provide modest improvements to iron status and hemoglobin (Werner et al. 2022b). A community-based intervention with small fish in young children led to greater muscle mass and a larger mid-upper-arm circumference (MUAC) in rural Malawi (Gibson et al. 2003). A complementary food supplemented with small fish powder led to greater weight gain in children in rural Malawi (Lin et al. 2008). Small fish powder was used to effectively treat rickets in children in Nigeria (Thacher et al. 2015). Consuming small fish (omena) three to five times a week was shown to optimize children's intake of micronutrients, including zinc, iron, calcium, and B12, in rural Kenya (Ferguson et al. 2015). Unfortunately, consumption of these foods during critical growth periods remains low in many regions, even in populations where many individuals rely on fishing for their livelihoods, and consumption of fish is highly disparate between and within countries (FAO 2022).

A recent systematic review of research on fish and fish-based products for nutrition and health outcomes during the first 1,000 days of life in LMICs, including 10 impact evaluations, measured consumption of fish or fish-based complementary food products in children aged 6–24 months (Byrd et al. 2022). The impact evaluations did not show strong evidence that fish consumption by children improves child growth; however, the studies were highly heterogeneous in their design and likely underpowered to detect an effect. Results from observational studies were mixed but provided evidence that adding fish to child diets is associated with improved nutrition outcomes, such as reducing the risk of anemia and improving vitamin D status.

Accessibility

Lack of accessibility is a barrier that prevents some populations from consuming fish, even in fishing households. One proposed way to overcome this barrier is to promote sustainable fish production that increases the income of fishing households. Interventions could encourage the use of fishing gear designed to maximize the catch of larger mature fish, thereby increasing the supply of high-quality fish and raising fishers' income while also lessening the impact of harmful fishing practices on the marine environment and improving the long-term sustainability of fisheries. Outreach efforts could also encourage fishers to keep some fish for consumption by the family, especially young children, instead of selling the entire catch. Fishers could also reserve seafood with a lower market value but good nutritional value for household consumption and sharing (Cartmill et al. 2022).

Affordability

Several studies highlight potential economic barriers to household consumption of fish and suggest that lack of access is driven mainly by cost and seasonal unavailability of fish (Cornelson et al. 2016; Esilaba et al. 2017; Cartmill et al. 2022).

Acceptability

Fish consumption for children is not always acceptable. In Indonesia, families that reported believing that fish cause allergies or illness in young children delayed their introduction of fish in childhood feeding (Gibson et al. 2020). In Kenya, negative beliefs were identified about the effects of fish foods (Mbogah et al. 2020; Cartmill et al. 2022).

Food preferences may be another factor influencing the quantity of fish in the diet and whether or not fish is introduced in complementary feeding. In addition to beliefs and perceptions about the nutritional value of fish, caregivers' own dislike of fish and/or preferences for other foods may prevent them from including it in the complementary feeding period (Cartmill et al. 2022).

Household and Gender Dynamics

Household and gender dynamics have also been a documented barrier. Studies have documented the influence of multiple family members on the issue of whether fish is appropriate to feed to young children, and if so, which types. In some African contexts, for example, elders' advice was reported to conflict with the official recommendations of the Ministry of Health, putting healthcare workers in the difficult position of recognizing the respected social role of elders while also encouraging women to include nutrient-rich food sources like fish in their young child's diet (Cartmill et al. 2022). Gendered purchasing behavior may also play a role in whether fishing households consume fish, as men often decide whether to sell fish or save it for the family meal (Fiorella et al. 2014; Cornelson et al. 2016; Esilaba et al. 2017).

Fish Powder

Small fish species, dried and sometimes turned into a powder using simple processing methods such as mortar, pestle, and sieve, can be used to fortify complementary foods. Dried fish and fish powder are a relatively affordable animal-source food that provides not only animal protein but also omega-3 fatty acids, vitamin A, calcium, iron, and zinc (Roos et al. 2007). Because moisture is removed during the drying process, nutrients in fish powder are concentrated and can offer a source of DHA when added to

SQ-LNS, which is especially advantageous for infants 6–11 months old given their high nutrient needs relative to their low caloric needs (Dewey 2013, 2016). In many contexts, fish powder is also locally available and culturally acceptable, although strong taste can limit acceptability in some settings (Longley et al. 2014).

Summary of Select Fish Powder Intervention Trial Evidence

Some studies have provided evidence that adding dried fish to foods is a viable method for increasing key nutrients in the diet (Bogard et al. 2015; Folake and Otegbayo 2006; Omueti et al. 2009). A recent randomized controlled trial in Zambia showed that fish powder improved linear growth among infants receiving fish powder for six months, increasing LAZ scores by 1.26 and weight-for-age Z-scores by 0.95. The authors reported that levels of stunting among infants in the fish group decreased by 25.6% (from 74.6% at baseline to 49.0% at endpoint) (Chipili et al. 2022). However, these reported growth differences far exceed the usual range of impact demonstrated in other child nutrition interventions, such as an earlier study in Ghana that also included fish powder (Lartey et al. 1999), raising methodological concerns.

Additional studies demonstrated that when dried small fish are included in relatively easy-to-prepare recipes, they can increase the amount of calcium, iron, and zinc in children's diets, likely without displacing breast milk. A study in Zambia showed that processing the dried small fish into powder achieved the optimum nutrient density of iron, zinc, and calcium for the diets of children 6–11 months old (Byrd et al. 2021).

Meat

Consuming animal-source foods such as meat or “flesh foods” during the complementary feeding window is widely supported as a strategy for improving dietary quality and overall nutrition (Iannotti 2018; Karakochuk et al. 2017; Lee et al. 2013). There are many different types of meat, which vary widely in their nutritional properties. Meat offers a good source of protein. So-called white meats, such as turkey and chicken, provide significant amounts of B vitamins, potassium, selenium, and phosphorus but have lower iron content than red meat counterparts. Beef contains large concentrations of bioavailable iron, zinc, and vitamin B12 as well as the fatty acid oleic acid and compounds such as creatine, conjugated linoleic acid, and glutathione. Pork is a significant source of thiamin and moderate amounts of selenium and zinc. Organ meats, particularly liver and kidney, are among the most nutrient-dense meat options, with high values for iron, zinc, copper, vitamin A, B vitamins, and selenium.

Affordability

The expense of meat is often cited as a major barrier to their use for infants. The fact that the consumption of meat in young children aged 6–24 months varies widely among LMIC contexts suggests that affordability is one of multiple influential determinants (Krebs et al. 2011).

Acceptability

Ground or pureed meats have been shown to be well accepted by infants as young as 6 months of age (Krebs et al. 2006) and in some cultures are routinely offered at this age. However, the introduction of meat is often delayed until later in the complementary feeding window (Ruel and Menon 2002). More clear evidence and communication on the role of iron-rich meat consumption on cognitive potential and linear growth in children may lead to better acceptance of the incorporation of meat into the diet of this target population (Krebs et al. 2011).

Household and Gender Dynamics

Intrahousehold food distribution plays a role in meat consumption for young children. In many contexts, "luxury" foods such as meat are preferentially allocated to the male household heads, leaving small to insignificant portions for women and children (Harris-Fry et al. 2018).

Plant-source foods

Fruits and Vegetables

Plant-source foods such as fruits and vegetables are components of dietary diversity food groups recommended daily for young children in addition to breast milk. Fruits and vegetables have long been considered vital parts of a nutritious diet, with additional benefits from high fiber content; however, because of their high water content, the concentration of most micronutrients is relatively low. The exception is vitamin A, found in high density in some fruits and vegetables such as carrots, mangoes, papaya, dark green leafy vegetables, pumpkins, and orange sweet potato (UNICEF 2020a). Dark green leafy vegetables also provide higher densities of other critical nutrients. WHO Guiding Principles on Complementary Feeding have stated that vitamin A–rich fruits and vegetables should be eaten daily by young children based on the health benefits associated with preventing vitamin A deficiency and the likelihood that consumption of such foods will also help meet the needs for many other vitamins (WHO 2012).

Overall, the micronutrient density of most fruits and vegetables is considered too low to contribute to the micronutrient intake of children aged 6–24 months, given the limited quantities of these foods young children can consume. The value of offering fruits and vegetables as a part of the complementary diet may therefore center on helping children accept and develop a taste for these foods, which play an important role in preventing some noncommunicable diseases later in life (Smith et al. 2022). Several studies have shown that providing vegetables as first foods increased future vegetable consumption and thus may be an effective strategy for improving later vegetable consumption (Rapson et al. 2021, 2022; Moss et al. 2020).

In some contexts, interventions that have incorporated fruits and vegetables into dietary modification—including counseling on the consumption of animal-source foods and orange-red fruits—improved dietary diversity (Lassi et al. 2013). However, research is relatively limited on the specific impacts of fruit and vegetable consumption in the complementary feeding phase and on the breakdown of nutritional impacts by food subgroups as well as the affordability, acceptability, availability, perishability, and convenience of these key food subgroups in varying contexts. More detailed guidelines regarding the recommended amount and frequency of consumption of such foods using local food composition data is needed.

Food Safety

Food safety is an important consideration for fruits and vegetables, which carry risk of microbial contamination, spoilage, and contamination from insects, animals, and bacteria that can lead to diarrhea and nutrient loss. Supporting an enabling environment for hygienic preparation, storage, and use of fruits and vegetables, such as washing raw produce with clean water and storing in a cool place, is critical (UNICEF 2021a).

Nuts and Legumes

Legumes (plant components from the Fabaceae family), and more specifically pulses—the edible seeds from legume plants, including beans, lentils, and peas—are grown and consumed globally. In terms of global production and consumption across all age groups, the major varieties include the common bean, chickpea, dry pea, lentil, cowpea, mung bean, urd bean, and pigeon pea. Pulses have higher levels of protein (roughly double the amount of protein found in wheat and three times that of rice), dietary fiber, and minerals than all major cereals. Of the most common pulses, lupin has the highest level of protein, at 34 grams per 100 grams, followed by the faba bean (25g) and lentil (24g); however, protein content varies considerably between varieties and is affected by both genetic and environmental factors (Rawal et al. 2019). It must also be noted that the plant-based amino acids of pulses have lower bioavailability than animal-based protein and include some antinutrients such as phytate and alpha amylase that interfere with digestion (Lassi et al. 2013). While content varies across variety, many pulses are also very high sources of several micronutrients such as B vitamins like folate and low to moderate sources of nutrients such as iron, magnesium, phosphorus, and zinc (Rawal et al. 2019; Foyer et al. 2016).

Similar to pulses, nuts and seeds are plant-based protein sources, but limited information exists on their role specifically in the complementary feeding period. Nutritional composition varies widely between individual types of nuts and seeds in terms of content of proteins and fats, ratio of mono- and polyunsaturated fats, and amounts of specific vitamins and minerals and bioactive compounds. However, most nuts and seeds contain the essential omega-3 fatty acid, alpha-linolenic acid, as well as dietary fiber, calcium, magnesium, and zinc (Dodevska et al. 2022).

Globally, the average adult consumption of legumes, in grams per capita per day, ranges from 33–34 in Latin America and the Caribbean, South Asia, and Sub-Saharan Africa to 1 in the Caucasus and Central Asia (Rawal et al. 2019). There is only limited on the consumption of nuts and legumes in the complementary feeding phase and the role of these foods in the micronutrient status of young children. No evidence was readily identified on the relationship between nut and/or legume consumption in the complementary feeding phase and future growth and development.

Affordability

Cross-country data on consumer prices show that pulse cost, relative to that of alternative sources of protein, has risen in most regions of the world other than Sub-Saharan Africa. This has occurred amid a decline in the consumption of pulses globally and a rise in share of animal-source foods in diets in most regions of the world.

Acceptability

Although some households may avoid feeding peanuts to older infants and young children because they perceive a risk of allergy, this concern is not backed up by the latest research. Consumption of pulses by young children may also be constrained by historical traditions and cultural preferences that vary in typical diets provided in the complementary period. Some studies, such as one in Ethiopia, showed the consumption pulses by children was minimal even pulse-growing areas. Mothers expressed a disinterest in using pulse crops in complementary foods, instead preferring to feed their children traditional cereals, roots and tubers (Mesfin et al. 2015). However, interventions such as training for health extension workers on the use of pulses for complementary food show promise for increasing adoption (Teshome et al. 2020). Long cooking time has also been noted as a barrier, but this can be effectively countered by soaking and pressure cooking.

Feasibility

Legumes have several limitations: yields can fluctuate widely from year to year, they are susceptible to biotic stress and have a high phosphorus requirement, and they are less profitable than other crops such as cereals (Semba et al. 2021).

Other Food-Based Interventions

Research is emerging on the potential role of nontraditional foods—such as spirulina, moringa foods, and insects—in the complementary diet. Despite the science on the nutritional importance of unconventional animals to the diets and livelihoods of low-income communities, issues such as the potential risks of zoonotic diseases, environmental impacts, and personal and political acceptance remain challenges. Additionally, while these foods are attracting growing interest owing to their high content of protein, essential amino acids, vitamins, and minerals, their use and impact specifically in the complementary feeding period have not been well studied (Van Huis 2016; Bleakley and Hayes 2017; Mwangi et al. 2022; Grosshagauer et al. 2020, 2021).

The nutritional impact of cereal-based porridges also needs consideration, given their nearly universal use in the complementary feeding phase globally. While fortified cereals may have an impact on iron status in areas with high iron deficiency, the potential for cereals to displace other nutrient-dense foods is of concern and warrants global recommendations. Meeting the high nutrient needs of young children with diets based predominantly on cereals and legumes is challenging. Underused micronutrient-rich foods, such as those from animal sources and indigenous or traditional trees and plants, could help address complementary feeding nutrient gaps. Some underused micronutrient-rich foods meet or exceed target micronutrient densities for complementary foods (per 100 kcal) but may be unfeasible for an infant to consume in large amounts due to lack of palatability. As this is a new area for research, issues to consider include overcoming potential aversions to these novel foods, factoring in opportunity costs, assessing environmental impacts, planning for sustainable harvesting, pairing new foods with nutrition education, and being aware of and sensitive to cultural dietary restrictions (Kuyper et al. 2013).

Home Fortificants

Multiple micronutrient powders (MNPs) were originally developed for children 6–23 months old and meant to be mixed with complementary foods. In 1997 Dr. Stanley Zlotkin developed the MNP "Sprinkles" to help address iron deficiency. In 1996 ready-to-use therapeutic food (RUTF) (like Plumpy'Nut) was developed to treat severe malnutrition. In 2000–2002, SQ-LNS, based on the same type of food-based matrix used for RUTF but using a much smaller quantity of food, was developed not to treat but to *prevent* malnutrition.

Programs that combine home fortification products with infant and young child (IYCF) feeding interventions may contribute to improved IYCF practices in some settings by:

- Establishing an enabling environment to support IYCF
- Reinforcing key IYCF messages
- Being integrated into a comprehensive package that includes enhanced social and behavior change communication for IYCF
- Triggering enhanced IYCF trainings for community health workers
- Improving the demand for and delivery of community health worker services

Home fortification consists of adding specialized, nutrient-filled products such MNPs or food-based complementary food supplements (CFSs) such as small-quantity lipid-based nutrient supplements (SQ-LNS) and full-fat soy flour (and soy protein isolate) with a vitamin-mineral mix to foods prepared at home (HF-TAG 2023). The following tables compare the nutrient content of MNPs and SQ-LNS, according to the World Food Programme specifications, with revised iLiNS Project formulation of SQ-LNS in parentheses.

Table 2. Nutrient content of MNPs and SQ-LNSs

Nutrient	MNP	SQ-LNS
Vitamin A (mcg)	400	400
Thiamin (mg)	0.5	0.3 (0.5)
Riboflavin (mg)	0.5	0.4 (0.5)
Niacin (mg)	6	4 (6)
Vitamin B6 (mg)	0.5	0.3 (0.5)
Folate (mcg)	150	133 (150)
Vitamin B12 (mcg)	0.9	0.5 (0.9)
Vitamin C (mg)	30	15 (30)
Vitamin D (mcg)	5	5
Vitamin E (mg)	5	4 (6)
Copper (mg)	0.56	0.34
Iodine (mcg)	90	90
Iron (mg)	10	6 (9)
Selenium (mcg)	17	20
Zinc (mg)	4.1	8

Nutrient	MNP	SQ-LNS
Energy (kcal)	0	118
Fat (g)	0	8
N-3 fatty acids (g)	0	0.42 (0.58)
N-6 fatty acids (g)	0	0.8 (4.5)
Protein (g)	0	2.4
Calcium (mg)	0	280
Magnesium (mg)	0	40
Manganese (mg)	0	1.2
Phosphorus (mg)	0	196 (190)
Potassium (mg)	0	200
Choline (mg)	0	10.4
Pantothenic acid (mg)	0	1.8 (2)
Biotin (mcg)	0	9
Vitamin K (mcg)	0	30

Source: WFP generic specifications . https://foodsafetyqualitypublic.manuals.wfp.org/docs/specifications-index

Micronutrient Powders

MNPs are sachets of powder that can be used to fortify food at the household level, without significantly changing the taste, color, or texture of the food. While the exact composition of MNPs varies based on type, World Food Programme technical specifications advise inclusion of vitamins A, D3, E, B1, B2, B6, B12, niacin, folic acid, vitamin C, iron, zinc, copper, selenium, and iodine (WFP 2016). Micronutrient supplementation to enhance micronutrient adequacy of the complementary diet has been widely used because of its cost-effectiveness, particularly in contexts where available foods cannot provide young children with their micronutrient needs. For more than a decade, strong evidence has shown the efficacy of MNPs in preventing and treating anemia and iron deficiency in children aged 6–23 months (Gera et al. 2009; Allen et al. 2009; De-Regil et al. 2011, 2017; Locks et al. 2017). A meta-analysis of all efficacy trials conducted in controlled settings concluded that MNPs containing 10–12.5 mg of iron are as effective as iron drops in treating anemia and resulted in better acceptance. Scientific evidence supports the efficacy and bioavailability of MNPs, primarily among moderately anemic children aged 6–24 months in a variety of settings (Dewey et al. 2009; Suchdev et al. 2020). Based on the results of many peer-reviewed published studies among children under age 5, MNPs have been increasingly accepted as efficacious to reduce anemia and a good way to address widespread deficiencies of other micronutrients (Zlotkin et al. 2005; De Pee 2008).

WHO recommends home fortification with iron-containing MNPs for young children in settings where nutrient-rich foods are inaccessible or unaffordable or where the prevalence of anemia in children is greater than 20 percent (WHO 2016). The integration of MNP into infant and young child feeding programs should always be coupled with counselling on its use and nutrition education to improve complementary feeding practices. MNP integration into infant and young child feeding programs has been shown to incentivize participation, increase caregiver knowledge on appropriate complementary feeding (Locks et al. 2017; McLean et al. 2019) improve the consistency of complementary foods (Michaux et al. 2014; Osei et al. 2014), facilitate timely initiation of solid foods at 6 months of age, improve dietary diversity, and improve population-based feeding indicators (Locks et al. 2017, 2018). It may also increase linear growth in children (Lanou et al. 2019).

MNPs were included in the *Lancet*'s 2008 "Maternal and Child Undernutrition" Special Series and later named by the World Bank as one of 13 efficacious and highly cost-effective interventions to improve the nutrition of young children. Since 2015, MNPs have been scaled to many countries. UNICEF has to a large degree been responsible for the storage and distribution of MNPs. As programmatic guidance by WHO and the Home Fortification Technical Advisory Group were harmonized, a number of suppliers started producing MNPs and agencies and governments started implementation at larger scale (HF-TAG 2011). The demand for MNPs increased from approximately 27 million sachets in 2007 to 1.2 billion sachets in 2017 (UNICEF 2021b).

Although MNPs have been evaluated in the context of small-scale projects, there has been a scarcity of large-scale effectiveness studies and documentation of best practices for successful integration into existing health platforms. There is thus a gap on how to implement home fortification with MNPs at scale with documented program learnings (McLean et al. 2019). Further implementation research for MNP programming is also needed on policy development, formative research, delivery mechanisms, social and behavior change communication, and monitoring and evaluation to ensure that MNPs reinforce appropriate complementary feeding practices (Siekmans et al. 2017; UNICEF 2020a). Additional understanding of what it takes to address barriers in implementation and uptake is also needed.

Availability

MNPs for point-of-use fortification of complementary foods are a niche product used in public health programs. Availability has depended largely on UNICEF as the biggest buyer of MNPs, followed at a distance by governments and others. However, some market-based approaches have undergone trials. In Bangladesh, BRAC and GAIN carried out a nationwide community-based initiative involving home fortification with MNPs to improve micronutrient status and reduce anemia among children aged 6–59 months. MNPs were manufactured by a leading national pharmaceutical company and were distributed through the Social Marketing Company (SMC) and a retail distribution channel (Afsana et al. 2014).

Issues affecting the supply of MNP products also include cost, intellectual property rights to Sprinkles, quality assurance processes and requirements, packaging and labeling, local production capacity, and demand. In the case of large-scale distribution compared with the controlled research conditions associated with small-scale trials, there is less control over storage practices, the instructions provided to and perceived by end users (or caregivers), and compliance. For end users, the quality of the product consumed will affect both adherence and, most importantly, its efficacy in preventing or treating micronutrient deficiencies. As the number of MNP producers increases, there is an increased risk that the final product will not meet quality criteria (de Pee et al. 2008).

Some have suggested that demand be increased by ensuring availability and distribution of MNPs through commercial channels among middle-class consumers. This may allow the product to be subsidized or distributed for free among groups with lower socioeconomic status or other specific populations, such as those affected by an emergency. In this model, the product as well as its branding would be the same for the different socioeconomic groups (de Pee et al. 2008).

In recent years, availability has also been impacted by the long-term logistical consequences of the COVID-19 pandemic, which caused major disruptions to the global shipping industry, affecting availability of commodities like MNPs. MNP products were vulnerable to the disruptions to global airfreight, as well as logistical bottlenecks created by border closures, export bans, and reductions in sea, air, and road transport—factors that can have an impact on the production of finished products if manufacturers rely on the importation of raw materials and packaging (UNICEF 2021b).

Accessibility

WHO included MNPs in the 2019 update of their Essential Medicines List (EML) and Essential Medicines List for Children (EMLc) (UNICEF 2021b). These guidance documents confirm that MNPs should be considered an essential product that can have an impact on public health. It is also a step toward making MNPs more accessible to children in need and to ensure greater cost-effectiveness in delivery through health systems.

Distribution of MNPs through nonhealth systems is innovative but challenging. The idea of distributing vouchers for MNPs that can be redeemed at a shop (Tumilowicz et al. 2019a) reduces the commodity storage and management requirements for the health system and is also being attempted for other health and nutrition products. It could provide a way to give certain consumers free access to MNPs through a voucher, whereas consumers with more purchasing power would be able to buy it. The simultaneous introduction of these two new distribution systems—purchases and vouchers—was the subject of a trial in Mozambique and found to be challenging. At the same time, this experiment revealed the resourcefulness and commitment of health workers, who identified and implemented solutions to logistical problems, adapting distribution schemes to local circumstances (Tumilowicz et al. 2019b; Roschnik et al. 2019).

Feasibility

Over the past decade MNP programs have been successfully introduced in many countries. Rwanda is one of the first countries to successfully scale up home fortification subnationally with MNPs (McLean et al. 2019). Yet even with a decade of efforts to introduce and scale up MNPs, most of the programs documented in the peer-reviewed literature have been modest in scale, implemented over relatively short periods, and dependent on significant external support (Pelletier and De Pee 2019). Although much has been published on MNP intervention impact at a small scale, there has been little formal documentation of lessons on how to effectively transition to scaled implementation that reaches a large population and achieves high adherence (Nyhus et al. 2017; Vossenaar et al. 2017).

MNP programs commonly report feasibility challenges related to utilization, adherence, acceptability, supply chain management, infrastructure and human resource capacity, and monitoring. Research studies find that these issues can be mitigated with sufficient investment in supervision and monitoring. Daily visits by health agents to caregivers have proven a successful strategy to improve adherence, though this approach may not be sustainable within existing health platforms (McLean et al. 2019). Continued success depends on adequate resources for capacity development, refresher training, and responsive monitoring. Sustainability of MNP supply and distribution is of concern, as two-thirds of all MNP interventions are currently funded entirely by development partners. Programs aiming for long-term sustainability must consider careful targeting of MNP interventions and use of existing infrastructure and systems.

Acceptability

Clear labeling and protective packaging against heat and humidity exposure can boost consumer acceptability while also preserving the shelf life and quality of the product. In a review of MNP trials, micronutrient powders are well accepted, but adherence is variable and not better than adherence achieved in infants and young children receiving standard iron supplements as drops or syrups; however, few studies have compared these interventions (De-Regil et al. 2013). Other studies confirm variability in self-reported acceptability of MNPs and adherence (Dusingizimana et al. 2021). Caregivers frequently cited the impact of MNPs on taste and sensory characteristics—contrary to the typical statement that MNPs are virtually tasteless powders that children cannot detect in food (Sutrisna et al. 2018). As infants age and taste preferences develop, the issue of child acceptability may evolve with their increased resistance to changes in texture or taste of foods. Caretakers should be informed that this may happen and be offered ways to minimize its impact, such as mixing MNPs with flavorful foods and larger quantities of food (Pelletier and De Pee 2019).

Small-Quality Lipid-Based Nutrient Supplements

Small-quantity lipid-based nutrient supplements (SQ-LNS) are small packets of a nutrient-dense paste that can be added to homemade foods or consumed directly from the pack as a snack. They are designed to prevent malnutrition in settings where vulnerable populations are likely to have multiple micronutrient gaps in their typical diets. Whereas ready-to-use therapeutic food (RUTF), with a daily dose of ≥ 500 kcal/day based on body weight and desired outcome, is intended to treat severe acute malnutrition, SQ-LNS is designed specifically to *prevent* malnutrition among children aged 6–24 months. SQ-LNS provides multiple micronutrients embedded in a small quantity of food (~20 g/day, 100–120 kcal/day). The composition of SQ-LNS can vary but typically includes vegetable oil (e.g., canola/rapeseed or soybean oil rich in omega-3 fatty acids), legumes (e.g., peanut, chickpea, lentil, and/or soy), milk powder, and the daily recommended amounts of essential fatty acids (alpha-linoleic acid and linoleic acid) and micronutrients (such as vitamin A, B vitamins, and iron), as well as lower amounts of macro-minerals such as calcium, potassium, phosphorus, and magnesium. These technical specifications are outlined by the World Food Programme for SQ-LNS. SQ-LNS is considered a type of home fortification and, like MNPs, can be mixed with foods prepared for young children to enrich nutrient content. Unlike MNPs, however, SQ-LNS can be eaten as is, if preferred (University of California, Davis, 2023).

Several studies have evaluated SQ-LNS for efficacy and effectiveness in promoting growth and development, with varied results. Although some early studies showed positive effects of SQ-LNS provision on linear growth (Adu-Afarwuah et al. 2007; Iannotti et al. 2014b), motor development (Adu-Afarwuah et al. 2007; Prado et al. 2016b), and walking (Prado et al. 2016a) in infants and young children (from 6 to 18 months), others showed limited or no effects (Phuka et al. 2008; Maleta et al. 2015; Prado et al. 2016c). Lipid-based nutrient supplement trials (20- to 54-g rations) that investigated morbidity outcomes in infants and children showed an increase in diarrhea or no effect or could not show any evidence for noninferiority (Unger et al. 2017; Adu-Afarwuah et al. 2007; Iannotti et al. 2014b; Mangani et al. 2014; Bendabenda et al. 2016), whereas two studies found a beneficial effect on diarrhea incidence (Huybregts et al. 2012; Luby et al. 2018).

The evidence base for the efficacy of SQ-LNS was enhanced by a recent meta-analysis of numerous randomized trials that included a total of more than 37,000 children. The analysis showed a reduced relative risk of multiple adverse outcomes, including mortality (by 27%), severe wasting (by 31%), severe stunting (by 17%), iron deficiency anemia (by 64%), and developmental delay (by 16–19%) between 6 and 23 months of age (Aguayo et al. 2023; Dewey et al. 2021, 2022; Prado et al. 2021; Wessells et al. 2021; Stewart et al. 2020). For most outcomes, the beneficial effects of SQ-LNS were evident regardless of region (when comparing Africa and South Asia), stunting burden, malaria prevalence, sanitation, or water quality. However, greater effects on child development outcomes and on severe wasting or stunting were seen in sites with a higher burden of stunting or wasting or poorer water quality or sanitation.

The effects of other fortified products, such as MNPs, on iron deficiency and anemia are similar to those of SQ-LNS (Suchdev et al. 2020), but the beneficial effects of MNPs on survival, growth, and development have not been reported in meta-analyses. SQ-LNS, therefore, have now been uniquely recognized as the preventive intervention for children, with a positive impact documented for each of these outcomes. Based on this evidence, there is a growing consensus among technical experts from key organizations, including UNICEF, WFP, USAID, the University of California, and the Bill & Melinda Gates Foundation, that SQ-LNS should be scaled up for children in need aged 6–23 months. The recommendation, stated in the 2021 *Lancet* Series on Maternal and Child Undernutrition, includes the qualification that the provision of SQ-LNS should always occur alongside other interventions to improve children's diets. Additionally, SQ-LNS has been shown to serve as an incentive for service delivery and program participation, such as connection to a community health worker and attendance in behavior change communication (Matias et al. 2017), participation in acute malnutrition screening (Becquey et al. 2019), and vaccine uptake (USAID Advancing Nutrition 2022). Further discussion is warranted on the specific priority subpopulation within children aged 6–23 months that is recommended to be targeted and how these recommendations interface with challenges related to supply and cost.

Affordability

While some consider the cost of these products prohibitive for integration into routine programming, four studies of costs and cost-effectiveness, as well as the Copenhagen Consensus paper written in light of the emerging evidence on the cost-benefit analysis of preventive SQ-LNS, suggest that SQ-LNS are a highly cost-effective intervention (Adams et al. 2022; Hoddinott et al. 2023). Thus, SQ-LNS has been suggested as a cost-effective, critical component of essential nutrition interventions promoting child survival, growth, and development when integrated into a core package of counseling and support for continued breastfeeding and a diverse nutritious diet.

Acceptability

SQ-LNS has been shown to be highly acceptable to caregivers and children, with high average compliance (70–100%) (UNICEF 2023). However, programs need to consider household rations in highly food-insecure contexts. Scaling up the delivery of supplements such as SQ-LNS depends on understanding private demand and mitigating policy-relevant factors that might influence demand. For example, a year-long market trial in Burkina Faso in which participants paid for the product revealed low levels of demand relative to the recommended supplementation regimen of one sachet per child per day and very high price elasticity, especially for repeat purchases (Lybbert et al. 2016).

Longitudinal willingness-to-pay (WTP) data from contingent valuation studies that were integrated into randomized controlled nutrition trials in Ghana and Malawi were evaluated to estimate the perceived individual value of SQ-LNS during pregnancy, postpartum, and early childhood. This study found that average stated WTP for a day's supply of SQ-LNS was more than twice as high in Ghana than Malawi, indicating that demand for SQ-LNS (and by extension, the options for effective delivery of SQ-LNS) may be highly context specific. Other factors associated with WTP, including intervention group, household socioeconomic status, birth outcomes, child growth, and maternal and child morbidity, were examined. In both sites, WTP was consistently negatively associated with household food insecurity, indicating that subsidies might be needed to permit food-insecure households to acquire SQ-LNS if it is made available for purchase. In Ghana, WTP was higher among heads of household than among mothers, which may be related to control over household resources (Adams et al. 2018). In settings where SQ-LNS are likely to be effective and policymakers choose to promote them, a hybrid distribution system may emerge that reaches target consumers through both public channels and retail outlets (Lybbert 2011). Where private demand is low, higher levels of public investment will be required to reach much of the target population of women and children (Adams et al. 2018).

Cross-Cutting Barriers and Enablers for Uptake of Nutrition Interventions in Policies and Programs

Availability

Several factors reduce the availability of nutritious foods within markets and households, including poor production, inadequate storage and distribution, and supply chain issues. Vulnerabilities and shocks to the food system due to climate change, seasonal fluctuations, diseases, conflicts, political instability, unemployment, and rising food prices can also impact food availability and livestock and crop production. Even when caregivers can afford such foods, the limited availability of nutritious foods is a barrier to consumption (UNICEF 2020a). Advances in agriculture and the livestock sector mean that national supplies of vegetables, fruits, eggs, fish, meat, and other nutritious foods are greater than ever, but they still fall short of population nutrient requirements, particularly in low-income countries and in regions affected by climate shocks and conflict (FAO et al. 2020).

Nutritious foods such as vegetables, eggs, and meat tend to be more perishable than staple cereals and tubers and are therefore more susceptible to distribution challenges and other supply chain disruptions (UNICEF 2021a). Furthermore, shortages in national supplies and seasonal scarcities continue to limit the availability of nutritious foods, particularly in rural Sub-Saharan Africa, in remote settings, and in countries affected by climate shocks or conflict.

In a UNICEF project soliciting maternal perspectives on food and feeding children (Schmied et al. 2020), one in three mothers reported that food availability is a major obstacle to healthy eating. Generalized food shortages as well as limited availability of quality or healthy foods were most frequently reported in lower-income countries.

Awareness

Programs have often failed to effectively communicate what is at stake with poor child nutritional intake and what reasonable alternatives exist for overcoming it. Awareness is lacking not only about what is needed to improve child diets but also about the urgency and economic implications of poor child nutrition for families, communities, and governments. Implementation science studies have increasingly documented how interventions can address these limitations and overcome access barriers (Warren et al. 2020).

Accessibility

Long distances to markets, poor roads and infrastructure, and humanitarian crises can make it difficult for families to access nutritious foods. Both urban and rural mothers described difficulty accessing food markets owing to lack of transport and access to roads (Schmied et al. 2020) .Conflict may impede access to production activities, such as planting, harvesting, and livestock movement. Children's access to nutritious foods is also influenced by food industry marketing and the presence or absence of a protective policy environment (UNICEF 2020a).

Evidence from the voices of mothers and regional analyses shows that families, especially lower-income families, struggle to find and access nutritious foods for their young children (UNICEF 2021a). Households—even farming households—are becoming increasingly reliant on food purchases rather than home production. Accordingly, proximity to food markets and shops is an important determinant of the quality of children's diets. Physical access is also a barrier in poor urban communities, where there are fewer shops selling nutritious foods and limited demand for these foods.

Affordability

Many nutritious foods—including vegetables, fruits, dairy, eggs, fish and meat—are more expensive than starchy staples because they cost more to produce, transport, and store, especially in low-income countries (Headey and Alderman 2019; Dizon and Herforth 2018; Alemu et al. 2019). The FAO reports that nutritious diets are five times more expensive than those that meet only energy needs, putting them beyond the financial reach of more than 3 billion people worldwide (FAO et al. 2020). The relative price of nutritious foods compared with staple foods is much higher in low-income countries than in high-income countries (Headey and Alderman 2019). Thus poor families in lower-income countries experience the widest gap between the price of nutritious foods and their daily income.

Studies have confirmed that the high cost of dairy, eggs, fish, and meat is associated with less frequent consumption among young children (Headey et al. 2018; Herforth and Ahmed 2015; UNICEF 2021a). The regional analyses by UNICEF and GAIN on the affordability of nutritious foods found evidence that nutritious foods are beyond the financial reach of poor households in all seven regions examined (UNICEF 2020b,c, 2021a). Recent modeling work on the economics of feeding infants by the World Bank Group show that the global poor are not able to meet the cost of complementary feeding that meets the nutrient needs of young children. As breast-milk intake increases, the cost of complementary feeding may decrease slightly, but it then rapidly increases as children begin to require a high volume of nutrient-dense foods. Combining food-based approaches with home fortificants such as SQ-LNS may substantially reduce the cost below $1 per day, provided SQ-LNS is distributed for free (Bai et al. 2021).

Affordability is especially a barrier to accessing nutritious foods that are rich in certain micronutrients, such as iron and zinc. The most affordable sources of these commonly lacking nutrients are liver, small fish, dark green leafy vegetables, milk, and eggs (Beal 2021). Meta analyses have shown, however, that nutrient-rich foods—particularly animal-source foods—can be too costly for many families, leading to poor dietary diversity in children (Sibhatu and Qaim 2018; UNICEF and GAIN 2019; FAO et al. 2019). Household purchasing power is often determined by income, intrahousehold allocation of financial resources, and the support provided by safety net programs, which can directly impact households' ability to purchase nutrient-rich foods for young children. Food prices can also be significantly impacted by humanitarian crises, which often interrupt food production, reducing supply (UNICEF 2020a).

When income is limited, families tend to prioritize the number of meals and full stomachs over the nutritional quality of foods for their young children. In addition, nutritious foods are increasingly crowded out by unhealthy processed and ultraprocessed foods that are cheap, convenient, and aggressively marketed to children and their families (UNICEF 2021a). Caregivers often face competing priorities in how to use their limited resources, and the perceived cost of nutritious foods is often outweighed by priorities of convenience, taste, or other social-emotional and subconscious food choice drivers.

Existing studies have limited evidence on the availability and cost of complementary foods needed to meet nutrient requirements. The complexities of child physiology and feeding practices make the realistic modeling of nutrient adequate diets challenging. However, recent attention to affordability includes the *Nutrition Reviews* supplement "Assessing Nutrient Gaps and Affordability of Complementary Foods: New Methods and their Application in Different Settings" (Nutrition Reviews

2021), the Cost of the Diet method used to calculate the cheapest possible cost of a locally available diet that satisfies all of an individual's nutritional requirements (Deptford et al. 2017), and papers such as "Nutrient shortfalls in young children's diets and the role of affordability" (Beal 2021), "The True Cost of Food" (Hendriks et al. 2023), and "Modelling the potential cost-effectiveness of food-based programs to reduce malnutrition" (Webb et al. 2021).

A recent study used the Comprehensive Nutrient Gap Assessment (CONGA) method to assess micronutrient gaps in the diets of young children across South Asia and Eastern and Southern Africa and the most micronutrient-dense available foods for filling these gaps. It found that there are common micronutrient gaps, including iron, vitamin A, zinc, folate, vitamin B12, and calcium. The top food sources of critical micronutrients are organs, small fish, dairy, ruminant meat, eggs, bivalves, and crustaceans. The CONGA analysis used price and spending data to compare the costs of nutrient-rich foods with households' typical food budgets and identified foods that were considered affordable because they could meet 50% of young children's nutrient needs while costing the household less than 10% of its food spending. While there are many affordable sources of vitamins A and B12, there are few affordable sources of iron and zinc in most countries. The most affordable sources of priority micronutrients are liver, small fish, dark leafy greens, milk, eggs, and in some countries, ruminant meat and groundnuts. Expansion of this type of country-specific affordability information holds value for identifying affordable sources of priority micronutrients specific to a local context (Beal 2021; Ryckman et al. 2021; GAIN and UNICEF 2021a,b; Ortenzi and Beal 2021; Beal et al. 2021a,b; White et al. 2021). Questions related to sustainable financing and costing remain, including how to mainstream food-based and home-based fortification into the budgeting and costing mechanisms of government programs.

Acceptability

Social and cultural norms play a role in many nutritional practices (Collison et al. 2015; Karmacharya et al. 2017; Mukuria et al. 2016). Social norms and family practices regarding child feeding can be nudged toward optimal practices, but locally tailored strategies are not easily scaled for widespread adoption. Caregivers' decisions about complementary feeding are often strongly influenced by other members of the family and community. Studies have reported mothers receiving information about child feeding, growth, and development from a mix of sources including mothers, mothers-in-law, and siblings. The term "influence of cultural custodians" has been used to describe a barrier to proper infant and young child feeding generated from cultural practices passed to mothers from respected family or community members (Nankumbi and Muliira 2015). While many reports on specific cultural food taboos are anecdotal and few quantitative or qualitative studies exist, it is clear that knowledge, beliefs, and preferences of family members (particularly mothers, fathers, grandmothers, and older women) strongly influence complementary feeding practices.

Food Safety

Poor food safety poses an additional risk for children in the complementary feeding stage. Contaminated water and complementary foods, poor hygiene practices, and unsafe storage and preparation of foods can result in diarrhea and malnutrition among children aged 6–24 months (Stewart et al. 2013). Fecal coliform, fecal streptococci, and specific pathogens such as *Salmonella, Campylobacter jejuni, Shigella, Vibrio cholera,* and *Escherichia coli* have all been isolated from complementary foods in low-resource countries (Muhimbula and Issa-Zacharia 2010; Barrell and Rowland 1980; Imong et al. 1989; Kung'u et al. 2009; Touré et al. 2013). Existing models of food safety intervention are limited in their ability to be scaled up and sustained locally. The inconvenience of the multiple steps required in such interventions limits the potential for sustained adoption, and it has proven challenging to sustain cost-intensive promotional activities to address food contamination pathways across populations (Soman and Zhao 2011; Dalton and Spiller 2012).

Caregiver Time

Work and household responsibilities constrain caregivers' time and affect their ability to prepare and feed nutritious foods at the recommended frequency and to practice responsive feeding—the reciprocal nurturing feeding practice between caregiver and child. In most contexts women are the primary caregivers of young children, and in many settings their time is taken by household chores such as fetching firewood or water, agricultural labor, and other nonfarm employment, leaving limited time and energy for childcare. In urban areas, working parents face significant time constraints that can limit the time they have available to prepare nutritious meals and engage in frequent feeding of their children. The choice of complementary foods is therefore often shaped by convenience and the desire to balance time for food preparation with other household demands. In some contexts, the concept of responsive feeding and attentive time and care of a child by the mother is countercultural. It will be useful to engage families in conversations about their expectations of caregiver time and how responsive feeding supports the growth and development of children in the long term (UNICEF United Kingdom 2016).

Mounting time pressures on mothers influence their child feeding decisions: two in three mothers in recent multi-country focus group discussions were constrained by insufficient time. Many mothers, particularly in urban areas, now work outside the home while continuing to shoulder the lion's share of domestic and caregiving responsibilities. Some rural mothers take on the additional burden of farming responsibilities as men migrate for work. Working mothers often compromise their own health and self-care to save time, and many turn to the convenience of processed and fast foods to feed their children (UNICEF 2021a).

In the UNICEF survey of maternal perspectives globally, one in four mothers reported that, given the pressures of work both outside and within the home, they lack the time to access foods and prepare healthy meals for themselves and their children. Mothers said they lack support from other household members and are therefore often too tired from work to access healthy ingredients or prepare nutritious meals. Most mothers devoted the time they did have to preparing food for their child rather than themselves. One suggestion for addressing these limitations is engaging fathers in child feeding, including providing tailored guidance on how to intentionally feed locally available and affordable foods to young children (Schmied et al. 2020). Obtaining fathers' perspectives and support related to child food choices and for reallocating tasks to free up mothers' time has been shown to be beneficial. However, male engagement often remains a weak and under-resourced component of child feeding programs (Warren et al. 2020).

Household and Gender Dynamics

Children's diets are also shaped by the distribution of food within the household, the prioritization of nutritious diets for children, women's decision-making in food purchasing, and gender preferences in feeding children, which vary within countries by geographic region, livelihood, and ethnic group. Interventions thus require decentralized strategies that are carefully tailored and targeted. Caregivers' ability to provide appropriate feeding and care to young children is also impacted by factors such as stress, emotional well-being, and mental health. These intrahousehold dynamics can be improved with support from social protection programs, interventions to support caring for the caregiver, and gender-sensitive health and nutrition programs that foster women's empowerment and men's participation in feeding, care, and child rearing (UNICEF 2020a).

Mothers continue to shoulder the responsibility for child feeding but do not always have the autonomy to choose what to feed their child. Additionally, unequal divisions of household responsibilities, mounting time pressures, and enduring social and cultural norms leave many mothers with insufficient time and autonomy to feed their young children well. Evidence consistently shows that when women have more decision-making power and control over household income, they tend to choose healthier foods and feeding practices for their children (Perez-Escamilla et al. 2018; UNICEF 2021a).

Ultimately, building local capacity to conduct strategic analyses, to shape relevant interventions based on cost and feasibility considerations, and to conduct ongoing adaptations are some key elements of success for large-scale programs. Closing program gaps will require ensuring that managers and frontline workers have a better understanding of critical child nutrition topics and greater motivation and skills to address mothers' individual concerns and to engage fathers and local food suppliers, strong coordination between agricultural extension and community health workers, and efforts to build mothers' self-efficacy (Nguyen et al. 2011, 2019; Rasheed et al. 2011; Sarrassat et al. 2019). Repeated engagement at the community level to motivate mothers and community health workers and fathers requires strategic choices on the part of program platforms and the use of multiple channels during early implementation.

Concluding Remarks

Meeting the micronutrient needs of the complementary diet is imperative for optimal child health and nutrition outcomes. No single food meets all micronutrient needs, and no sole approach (food-based or home-fortification intervention) will be able to completely fulfill the nutritional requirements of the growing child during the complementary feeding period of 6–23 months. However, several countries have achieved child nutrition targets, and much can be learned from these countries on how to optimize the dietary intake of young children. Their experiences show that complementary feeding interventions need to be integrated into food, health, WASH, and social protection sectors and need to include costing, financing, and accountability mechanisms, with actions taken at the levels of individuals, households, communities, public and private institutions, and policies.

Eggs, fish, and certain meats (namely organ and red meats) are among the most nutrient-dense foods, providing high content of protein and multiple micronutrients. While the evidence for the specific impact of the consumption of these animal-source, nutrient-rich foods on outcomes such as linear growth, morbidity, and mortality is still emerging, recent studies for eggs and fish suggest that children who consume higher levels of these nutrient-dense foods are more likely to meet daily nutritional requirements and may have better growth outcomes than those who do not. However, consumption of these animal-source foods by young children faces significant barriers. These include prohibitive cost, challenges along the value chain that impede distribution at scale, risk of pathogen contamination, and cultural norms that discourage giving certain animal-source foods to young children or assign their preferential consumption to older family members. Egg powder and fish powder overcome some of these barriers. They offer similar nutrients as their fresh counterparts but are more transportable (thus widening availability for some populations), have reduced risk of contamination, and are more affordable (the expense of production is outweighed by reduced transport and storage costs, longer shelf life, and easier dosage for use of smaller portions). Questions remain on how to effectively scale up distribution and adoption of these powders in various contexts.

While plant-based sources of protein such as legumes, nuts, and seeds offer high protein per gram and are more available and affordable than animal-source foods in many contexts, the reduced bioavailability of their amino acids and low density of other critical micronutrients denote the need for regular inclusion of other nutrient-dense foods or fortificants to make up for their limitations. The low nutrient density of fruits and vegetables suggests that these foods make a minimal contribution in meeting the micronutrient requirements of young children, though recent modeling studies have shown the value of vegetables in meeting nutrient requirements.

Some evidence, though, suggests that fruits and vegetables warrant inclusion in young children's diets because these foods are associated with taste formation and future consumption of healthy foods and also protect against noncommunicable diseases later in life. Behavioral economics may help better explain the drivers of people's food choices and changing behavior as well as how to scale up plant-based interventions that are also tailored to local contexts, commonly consumed foods, and traditional dishes.

Home fortificants serve an important role by meeting the micronutrient needs that locally available foods are not always able to fulfill. The evidence on MNPs and SQ-LNS suggests that these interventions hold promise for successfully enhancing the micronutrient quality of the child diet. MNPs have been shown to be cost-effective in preventing and treating deficiencies such as anemia, and in a recent meta-analysis SQ-LNS showed strong effects on mortality and growth. Next steps in research include investigating what it takes to implement these home fortificants at scale, how to develop and provide high-quality counseling and messaging, what guidance to offer on using home fortification products appropriately within a ration basket in highly food-insecure contexts, and what modalities will be most effective for sustainable financing.

Ultimately, context-specific approaches will need to combine diverse food-based approaches and home fortification products while ensuring that common barriers, including costs, availability, and cultural preferences, are being addressed. In addition to micronutrients, more attention should be directed to other nutrients such as essential fatty acids as well as to diet patterns throughout early childhood that maximize potential later in life. Practical guidelines, communication packages, and decision-making tools could be established to guide policy and programming, taking account of a rapidly changing environment and pressing concerns such as climate and ultraprocessed foods. Ultimately there is a need to drive food system transformation with a complementary feeding child diet lens, including the transition to feeding children after two years of age.

References (work-in-progress)

Adams, K.P., Vosti, S.A., Ayifah, E., et al. (2018). Willingness to pay for small-quantity lipid-based nutrient supplements for women and children: Evidence from Ghana and Malawi. Matern Child Nutr. 14:e12518. https://doi.org/10.1111/mcn.12518

Adams, K. P. et al. (2022). Effectiveness and cost-effectiveness of small-quantity lipid-based nutrient supplements (SQ-LNS) for preventing child malnutrition, improving child survival and promoting health development. Part 2: Costs, cost-efficiency and cost-effectiveness of interventions that include SQ-LNS. World Bank. https://go.nature.com/3iQ2R12

Adu-Afarwuah S, Lartey A, Brown KH, Zlotkin S, Briend A, Dewey KG. (2007) Randomized comparison of 3 types of micronutrient supplements for home fortification of complementary foods in Ghana: effects on growth and motor development. Am J Clin Nutr. 86:412–20.

Afsana K, Haque MR, Sobhan S, Shahin SA. (2014) BRAC's experience in scaling-up MNP in Bangladesh. Asia Pac J Clin Nutr. 23(3):377-84. doi: 10.6133/apjcn.2014.23.3.22. PMID: 25164447.

Aguayo, V.M., et al. (2023) Benefits of small-quantity lipid-based nutrient supplements for child nutrition and survival warrant moving to scale. Nat Food 4, 130–132. https://doi.org/10.1038/s43016-023-00703-2

Alemu, R, Block, S. A., Headey, D. D., et al. (2019). Where are nutritious diets most expensive? Evidence from 195 foods in 164 countries. Presented at the ASSA Annual Meeting, in Hilton Atlanta, Atlanta, January 5, 2019. https://www.aeaweb.org/conference/2019/preliminary/paper/RfTTNfGY

Allen, L.H., Peerson, J.M., and Olney, D.K. (2009) Provision of multiple rather than two or fewer micronutrients more effectively improves growth and other outcomes in micronutrient-deficient children and adults. J Nutr 139(5): 1022-30.

Aung-Than-Batu, Thein-Than, Thane-Toe. (1976) Iron absorption from Southeast Asian rice-based meals. Am J Clin Nutr. 29(2):219–225. https://doi.org/10.1093/ajcn/29.2.219 PMID: 130073

Bai, Yan et al. (2021) The Economics of Feeding Infants: Least-Cost Nutrient Adequate Diets from 6 to 23 months of age using Breastmilk and Locally Available Foods in 31 Low-Income Countries. http://dx.doi.org/10.1093/cdn/nzab045_005

Barrell R.A., Rowland M.G. (1980) Commercial milk products and indigenous weaning foods in a rural West African environment: a bacteriological perspective. *J Hyg (Lond)*. 84(2):191–202.

Baye, K., Abera, A., Chitekwe, S., Getachew, P., Hailemariam, A., Dibari, F., & Laillou, A. (2021). Whole egg powder makes nutritious diet more affordable for Ethiopia: A cost of the diet and affordability analysis. Maternal & Child Nutrition, e13274. https://doi.org/10.1111/mcn.13274

Beal, T. (2021). Nutrient shortfalls in young children's diets and the role of affordability. GAIN Briefing Paper 4. 10.36072/bp.4. https://www.gainhealth.org/sites/default/files/publications/documents/gain-briefing-paper-series-4-nutrient-shortfalls-in-young-childrens-diets-and-the-role-of-affordability.pdf

Beal, T., et al. (2021a). Comprehensive Nutrient Gap Assessment (CONGA): A method for identifying the public health significance of nutrient gaps. Beal et al. (2021). Comprehensive Nutrient Gap Assessment (CONGA): A method for identifying the public health significance of nutrient gaps.

Beal, T., et al. (2021b). Micronutrient gaps during the complementary feeding period in South Asia: A Comprehensive Nutrient Gap Assessment. http://dx.doi.org/10.1093/nutrit/nuaa144

Becquey et al. (2019). Impact on child acute malnutrition of integrating a preventive nutrition package into facility-based screening for acute malnutrition during well-baby consultation: A cluster-randomized controlled trial in Burkina Faso. PLOS Med. https://doi.org/10.1371/journal.pmed.1002877

Beesabathuni K, Lingala S, Kraemer K. (2018) Increasing egg availability through smallholder business models in East Africa and India. Matern Child Nutr. 14:e12667. doi: 10.1111/mcn.12667

Bendabenda J, Alho L, Ashorn U, Cheung Y, Dewey K, Vosti S, Phuka J, Maleta K, Ashorn P. (2016) The effect of providing lipid-based nutrient supplements on morbidity in rural Malawian infants and young children: a randomized controlled trial. Public Health Nutr. 19:1893–903.

Bimbo F, Bonanno A, Nocella G, Viscecchia R, Nardone G, De Devitiis B, et al. (2017) Consumers' acceptance and preferences for nutrition-modified and functional dairy products: a systematic review. Appetite. 113:141– 54. doi: 10.1016/j.appet.2017.02.031

Bleakley S., Hayes M. (2017). Algal proteins: extraction, application, and challenges concerning production. Foods, 6 (2017), p. 33. https://doi:10.3390/foods6050033

Bogard, J. R., Hother, A.-L., Saha, M., Bose, S., Kabir, H., Marks, G. C., & Thilsted, S. H. (2015). Inclusion of small indigenous fish improves nutritional quality during the first 1000 days. Food and Nutrition Bulletin, 36(3), 276–289. https://doi.org/10.1177/0379572115598885

Byrd, K. A., Pincus, L., Pasqualino, M. M., Muzofa, F., & Cole, S. M. (2021). Dried small fish provide nutrient densities important for the first 1000 days. Maternal & Child Nutrition, 17(4), e13192. https://doi.org/10.1111/mcn.13192

Byrd K.A., Shieh J., Mork S., Pincus L., O'Meara L., Atkins M, Thilsted S.H. (2022). Fish and Fish-Based Products for Nutrition and Health in the First 1000 Days: A Systematic Review of the Evidence from Low and Middle-Income Countries. Adv Nutr. 13(6):2458-2487. doi: 10.1093/advances/nmac102. PMID: 36166842; PMCID: PMC9776644.

Cartmill MK, Blackmore I, Sarange C, Mbeyu R, Cheupe C, Cheupe J, et al. (2022) Fish and complementary feeding practices for young children: Qualitative research findings from coastal Kenya. PLoS ONE 17(3): e0265310. https://doi.org/10.1371/journal.pone.0265310

Chipili G, Van Graan A, Lombard CJ, Van Niekerk E. (2022) The Efficacy of Fish as an Early Complementary Food on the Linear Growth of Infants Aged 6–7 Months: A Randomised Controlled Trial. *Nutrients*. 14(11):2191. https://doi.org/10.3390/nu14112191

Collison, D.K., et al. (2015) Acceptability and utility of an innovative feeding toolkit to improve maternal and child dietary practices in Bihar, India. Food Nutr Bull, 36(1): p.24-32

Cornelson L, Alarcon P, Hasler B, Amendah DD, Ferguson E, Fèvr EM, et al. (2016) Cross-sectional study of drivers of animal-source food consumption in low-income urban areas of Nairobi, Kenya. *BMC Nutr.* 2,70. doi: 10.1186/s40795-016-0109-z

Dalton AN, Spiller SA. (2012) Too much of a good thing: The benefits of implementation intentions depend on the number of goals. *J Cons Res*. 39(3):600–614.

de Pee S. (2008). Need, efficacy and effectiveness of multi vitamin/mineral supplements for young children and considerations for programs. In: Semba RD, Bloem MW, eds. Nutrition and health in developing countries, 2nd ed. Totowa, NJ, USA: Humana Press.

de Pee S, Kraemer K, van den Briel T, Boy E, Grasset C, Moench-Pfanner R, Zlotkin S, Bloem MW. (2008). Quality criteria for micronutrient powder products: report of a meeting organized by the World Food Programme and Sprinkles Global Health Initiative. Food Nutr Bull. 29 (3):232-41. doi: 10.1177/156482650802900309. PMID: 18947036.

Deptford, A., Allieri, T., Childs, R. et al. (2017) Cost of the Diet: a method and software to calculate the lowest cost of meeting recommended intakes of energy and nutrients from local foods. *BMC Nutr* 3, 26. https://doi.org/10.1186/s40795-017-0136-4

De-Regil, L.M., et al. (2011). Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age. Cochrane Database Syst Rev, 2011(9): p. CD008959.

De-Regil LM, Suchdev PS, Vist GE, Walleser S, Peña-Rosas JP. (2013) Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age (Review). Evid Based Child Health. Jan;8(1):112-201. doi: 10.1002/ebch.1895. PMID: 23878126.

De-Regil, L.M., Jefferds, M.E.D., and Pena-Rosas, J.P. (2017). Point-of-use fortification of foods with micronutrient powders containing iron in children of preschool and school-age. Cochrane Database Syst Rev, 2017; 11: p. CD009666.

Dewey, K. G. (2013). The challenge of meeting nutrient needs of infants and young children during the period of complementary feeding: An evolutionary perspective. Journal of Nutrition, 143, 2050–2054. https://doi.org/10.3945/jn.113.182527

Dewey, K. G. (2016). Reducing stunting by improving maternal, infant and young child nutrition in regions such as South Asia: Evidence, challenges and opportunities. Maternal & Child Nutrition, 12, 27–38. https://doi.org/10.1111/mcn.12282

Dewey KG, Yang Z, Boy E. (2009) Systematic review and meta-analysis of home-fortification of complementary foods. Matern Child Nutr., 5 (2009), pp. 283-321

Dewey, K.G. et al. (2021) Characteristics that modify the effect of small-quantity lipid-based nutrient supplementation on child growth: an individual participant data meta-analysis of randomized controlled trials. Am J Clin Nutr. 2021 Nov 2;114(Suppl 1):15S-42S. doi: 10.1093/ajcn/nqab278. PMID: 34590672; PMCID: PMC8560308.

Dewey, K. G. et al. (2022) Preventive small-quantity lipid-based nutrient supplements reduce severe wasting and severe stunting among young children: an individual participant data meta-analysis of randomized controlled trials. *Am. J. Clin. Nutr.* 116, 1314–1333.

Dizon, F., & Herforth, A. (2018). The cost of nutritious food in South Asia. Policy Research Working Paper, 8557. World Bank Group, Washington D.C.

Dodevska M, Kukic Markovic J, Sofrenic I, Tesevic V, Jankovic M, Djordjevic B, Ivanovic ND. (2022) Similarities and differences in the nutritional composition of nuts and seeds in Serbia. Front Nutr. 9:1003125. doi: 10.3389/fnut.2022.1003125. PMID: 36185649; PMCID: PMC9523690.

Dumas, SE, Lewis, D, Travis, AJ. (2018) Small-scale egg production centres increase children's egg consumption in rural Zambia. Matern Child Nutr. 14(S3):e12662. https://doi.org/10.1111/mcn.12662

Dusingizimana T, Weber JL, Ramilan T, Iversen PO, Brough L. (2021) A mixed-methods study of factors influencing access to and use of micronutrient powders in Rwanda. *Glob Health Sci Pract*. 9(2). 10.9745/GHSP-D-20-00422

Esilaba FA, Moturi WN, Mokua MA. (2017) Urban consumers' fish preferences and the determinants influencing fish selection and consumption: Case study of Nakuru Town, Kenya. *Int J Fish Aquat Stud*. 5(3):356–360.

Faber M, Malan L, Kruger HS, Asare H, Visser M, Mukwevho T, Ricci C, Smuts CM. (2022) Potential of Egg as Complementary Food to Improve Nutrient Intake and Dietary Diversity. *Nutrients*. 14(16):3396. https://doi.org/10.3390/nu14163396

FAO (Food and Agriculture Organization of the United Nations). (2013). FAOSTAT statistics database. Rome, Italy: FAO. Retrieved March 9, 2018, from http://www.fao.org/faostat/en/

FAO (2017) FAOSTAT. Retrieved from http://faostat.fao.org/default.aspx

FAO. (2022) The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation. Rome: FAO. https://doi.org/10.4060/cc0461en

FAO, UNICEF, World Food Programme, World Health Organization. (2019). Placing nutrition at the centre of social protection. Asia and the Pacific regional overview of food security and nutrition 2019. FAO, Bangkok.

FAO, International Fund for Agricultural Development, UNICEF, et al. (2020). The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets 2020. FAO, Rome.

Ferguson E, Chege P, Kimiywe J, Wiesmann D, Hotz C. (2015) Zinc, iron and calcium are major limiting nutrients in the complementary diets of rural Kenyan children. Matern Child Nutr. 11 Suppl 3(Suppl 3):6-20. doi: 10.1111/mcn.12243. PMID: 26778799; PMCID: PMC5066654.

Fiorella K, Hickey M, Salmen C, Nagata J, Mattah B, Magerenge R, et al. (2014) Fishing for food? Analyzing links between fishing livelihoods and food security around Lake Victoria, Kenya. *Food Security.* 6(6): 851–60. doi: 10.1007/s12571-014-0393-x

Folake, O., & Otegbayo, B. O. (2006). Chemical analysis and sensory evaluation of Ogi enriched with soybeans and crayfish. Nutrition & Food Science, 36(4), 214–217.

Foyer CH, et al. (2016). Neglecting legumes has compromised human health and sustainable food production. Native Plants, 2 (2016), p. 16112, 10.1038/nplants.2016.112

GAIN and UNICEF. (2021a). Affordability of nutritious foods for complementary feeding. https://www.gainhealth.org/resources/reports-and-publications/affordability-nutritious-foods-complementary-feeding

GAIN and UNICEF. (2021b). CONGA: Micronutrient gaps during the complementary feeding period. https://www.gainhealth.org/resources/reports-and-publications/comprehensive-nutrient-gap-assessment-conga-micronutrient-gaps-during-complementary-feeding-period

Gallegos-Riofrío, CA, Waters, WF, Salvador, JM, et al. (2018) The Lulun Project's social marketing strategy in a trial to introduce eggs during complementary feeding in Ecuador. *Matern Child Nutr*. 14(S3): e12700. https://doi.org/10.1111/mcn.12700

Gera, T., Sachdev, H.P., and Nestel, P. (2009) Effect of combining multiple micronutrients with iron supplementation on Hb response in children: systematic review of randomized controlled trials. Public Health Nutr, 12(6): p. 756-73

Gibson RS, Hotz C. (2001) Dietary diversification/modification strategies to enhance micronutrient content and bioavailability of diets in developing countries. Br J Nutr. 85(S2). S159–S166. https://doi.org/10. 1079/bjn2001309 PMID: 11509105

Gibson RS, Yeudall F, Drost N, Mtitimuni BM, Cullinan TR. (2003). Experiences of a Community-Based Dietary Intervention to Enhance Micronutrient Adequacy of Diets Low in Animal Source Foods and High in Phytate: A Case Study in Rural Malawian Children, Journal of Nutrition, Volume 133, Issue 11,2003, Pages 3992S-3999S, https://doi.org/10.1093/jn/133.11.3992S.

Gibson E, Stacey N, Sunderland TCH, Adhuri DS. (2020) Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, eastern Indonesia. PLoS One. 15 (4):e0230777. https://doi.org/10.1371/journal.pone.0230777 PMID: 32236144

Grosshagauer S, Klaus Kraemer, and Veronika Somoza. (2020) The True Value of Spirulina. J. Agric. Food Chem. 68, 14, 4109–4115.

Grosshagauer S, Pirkwieser P, Kraemer K and Somoza V. (2021) The Future of Moringa Foods: A Food Chemistry Perspective. Front. Nutr. 8:751076. doi: 10.3389/fnut.2021.751076

Harris-Fry, H.A., Paudel, P., Shrestha, N. et al. (2018) Status and determinants of intra-household food allocation in rural Nepal. *Eur J Clin Nutr* 72, 1524–1536. https://doi.org/10.1038/s41430-017-0063-0

Headey, D. D., & Alderman, H. H. (2019). The relative caloric prices of healthy and unhealthy foods differ systematically across income levels and continents. Journal of Nutrition, 149(11), 2020–2033. https://doi.org/10.1093/jn/nxz158

Headey, D., Hirvonen, K., & Hoddinott, J. (2018). Animal sourced foods and child stunting. American Journal of Agricultural Economics, 100(5), 1302–1319. https:// doi.org/10.1093/ajae/aay053

Hendriks, S. et al. (2023). The True Cost of Food: A Preliminary Assessment. http://dx.doi.org/10.1007/978-3-031-15703-5_32

Herforth, A., & Ahmed, S. (2015). The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. Food Security, 7(3), 505–520. https://doi.org/10.1007/s12571-015-0455-8

HF-TAG (Home-Fortification Technical Advisory Group). (2023) Home page. www.hftag.org

HF-TAG. (2011). Programmatic guidance brief on use of micronutrient powders (MNP) for home fortification. Geneva: HF-TAG.

Hirvonen Kalle and Abdulazize Wolle. (2018) Availability, access, and consumption of nutritious foods in the Afar region of Ethiopia (plus 5 large regions of Ethiopia). Secondary analysis of agricultural and food consumption data to assess the potential of nutrient dense foods reaching most children in each region. Alive & Thrive and IFPRI Reports.

Hoddinott, J., Larsen, B., and Razvi, S. (2023). Investing in nutrition – a global best investment case. https://copenhagenconsensus.com/sites/default/files/2023-03/Nutrition%20Best%20Investment%20Manuscript%20230211.pdf

Huybregts L, Houngbé F, Salpéteur C, Brown R, Roberfroid D, Ait-Aissa M, Kolsteren P. (2012) The effect of adding ready-to-use supplementary food to a general food distribution on child nutritional status and morbidity: a cluster-randomized controlled trial. PLoS Med. 9:e1001313.

Huybregts et al. (2019) PLOS Med. https://doi.org/10.1371/journal.pmed.1002892

Iannotti, L. L. (2018). The benefits of animal products for child nutrition in developing countries. Revue Scientifique et Technique (International Office of Epizootics), 37(1), 37–46. https://doi.org/10.20506/rst.37.1.2738

Iannotti, L. L., Lutter, C. K., Bunn, D. A., & Stewart, C. P. (2014a). Eggs: The uncracked potential for improving maternal and young child nutrition among the world's poor. Nutrition Reviews, 72(6), 355–368. https://doi.org/10.1111/nure.12107

Iannotti LL, Dulience SJ, Green J, Joseph S, Francois J, Antenor ML, Lesorogol C, Mounce J, Nickerson NM. (2014b). Linear growth increased in young children in an urban slum of Haiti: a randomized controlled trial of a lipid-based nutrient supplement. Am J Clin Nutr. 99:198–208.

Iannotti, L. L., Lutter, C. K., Stewart, C. P., Gallegos Riofrıo, C. A., Malo, C., Reinhart, G., … Waters, W. F. (2017). Eggs in early complementary feeding and child growth: A randomized controlled trial. Pediatrics, 140(1), pii: e20163459. https://doi.org/10.1542/peds.2016-3459

Iannotti, LL, Chapnick, M, Nicholas, J, et al. (2020). Egg intervention effect on linear growth no longer present after two years. *Matern Child Nutr*. 16:e12925. https://doi.org/10.1111/mcn.12925

Imong SM, Rungruengthanakit K, Ruangyuttikarn C, Wongsawasdii L, Jackson DA, Drewett R. (1989). The bacterial content of infant weaning foods and water in rural northern Thailand. *J Trop Pediatr*. 35(1):14–18.

Karakochuk, C. D., Whitfield, K. C., Green, T. J., & Kraemer, K. (2017). The biology of the first 1000 days. Taylor & Francis.

Karmacharya, C., et al. (2017) Grandmothers' knowledge positively influences maternal knowledge and infant and young child feeding practices. Public Health Nutr, 20(12): p. 2114- 2123

Kawarazuka N, Béné C. (2011). The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence. Public Health Nutr. 14(11):1927–1938. https://doi.org/ 10.1017/S1368980011000814 PMID: 21729489

Kim, S. S., Rawat, R., Mwangi, E. M., Tesfaye, R., Abebe, Y., Baker, J., … Menon, P. (2016). Exposure to large-scale social and behavior change communication interventions is associated with improvements in infant and young child feeding practices in Ethiopia. PLoS ONE, 11(10), e0164800. https://doi.org/10.1371/journal.pone.0164800

Kim et al. (2019). Behavior Change Interventions Delivered through Interpersonal Communication, Agricultural Activities, Community Mobilization, and Mass Media Increase Complementary Feeding Practices and Reduce Child Stunting in Ethiopia. Journal of Nutrition. Vol `49, Issue 8, p1470-1481. https://doi.org/10.1093/jn/nxz087

Krebs NF, Westcott JE, Butler N, Robinson C, Bell M, Hambidge KM. (2006). Meat as a first complementary food for breastfed infants: feasibility and impact on zinc intake and status. *J Pediatr Gastroenterol Nutr.* 42:207–14.

Krebs, N. F., Mazariegos, M., Tshefu, A., Bose, C., Sami, N., Chomba, E., Carlo, W., Goco, N., Kindem, M., Wright, L. L., Hambidge, K. M., & Study Group, C. F. (2011). Meat consumption is associated with less stunting among toddlers in four diverse low-income settings. *Food and nutrition bulletin*, *32*(3), 185. https://doi.org/10.1177/156482651103200301

Kung'u JK, Boor KJ, Ame SM, Ali NS, Jackson AE, Stoltzfus RJ. (2009) Bacterial populations in complementary foods and drinking-water in households with children aged 10-15 months in Zanzibar, Tanzania. *J Health Popul Nutr*. 27(1):41–52.

Kuyper E., Vitta B., and Dewey KG. (2013) Alive & Thrive Technical Brief Insight: Novel and underused food sources of key nutrients for complementary feeding.

Lanou, H.B., et al. (2019) 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(4): e12820.

Lartey A, Manu A, Brown KH, Peerson JM, Dewey KG. (1999) A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age. Am J Clin Nutr. 70(3):391-404. doi: 10.1093/ajcn/70.3.391. PMID: 10479202.

Lassi, Z.S., et al. (2013). Impact of education and provision of complementary feeding on growth and morbidity in children less than 2 years of age in developing countries: a systematic review. BMC Public Health, 13 Suppl 3: S13.

Lee, S. E., Talegawkar, S. A., Merialdi, M., & Caulfield, L. E. (2013). Dietary intakes of women during pregnancy in low- and middle-income countries. Public Health Nutrition, 16(8), 1340–1353. https://doi.org/10.1017/S1368980012004417

Lin CA, Manary MJ, Maleta K, Briend A, Ashorn P. (2008) An energy-dense complementary food is associated with a modest increase in weight gain when compared with a fortified porridge in Malawian children aged 6-18 months. J Nutr. 138(3):593-8. doi: 10.1093/jn/138.3.593. PMID: 18287372.

Locks, L.M., et al. (2017) 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(6).

Locks, L.M., et al. (2018) Infant and Young Child Feeding (IYCF) Practices Improved in 2 Districts in Nepal during the Scale-Up of an Integrated IYCF and Micronutrient Powder Program. Curr Dev Nutr, 2(6): p. nzy019.

Longley, C., Thilsted, S. H., Beveridge, M., Cole, S., Nyirenda-Banda, D., Heck, S., & Hother, A.-L. (2014). The role of fish in the first 1,000 days in Zambia. IDS Special Collection, September, 27–35.

Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, Stewart CP, Begum F, Hussain F, Benjamin-Chung J et al. (2018) Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. Lancet Glob Health. 6:e302–15.

Lutter, C. K., Iannotti, L. L., & Stewart, C. P. (2018). The potential of a simple egg to improve maternal and child nutrition. Maternal & Child Nutrition, 14(Suppl 3), e12678. https://doi.org/10.1111/mcn.12678

Lutter, C.K.; Caswell, B.L.; Arnold, C.D.; Iannotti, L.L.; Maleta, K.; Chipatala, R.; Prado, E.L.; Stewart, C.P. (2021). Impacts of an egg complementary feeding trial on energy intake and dietary diversity in Malawi. *Matern. Child Nutr. 17*, e13055.

Lybbert, T. J. (2011). Hybrid public–private delivery of preventative lipid-based nutrient supplement products: Key challenges, opportunities and players in an emerging product space. SCN News, 39, 32–39.

Lybbert, T. J., Vosti S. A., Adams K. P. & Guissou R. (2016). Household demand for child micronutrient supplementation in Burkina Faso. CEGA working paper no 55 http://escholarship.org/uc/item/7mf7z875

Makrides, M., Hawkes, J. S., Neumann, M. A., & Gibson, R. A. (2002). Nutritional effect of including egg yolk in the weaning diet of breast-fed and formula-fed infants: a randomized controlled trial. American Journal of Clinical Nutrition, 75(6), 1084–1092. https://doi.org/10.1093/ajcn/75.6.1084

Maleta KM, Phuka J, Alho L, Cheung YB, Dewey KG, Ashorn U, Phiri N, Phiri TE, Vosti SA, Zeilani M et al. (2015) Provision of 10–40 g/d lipid-based nutrient supplements from 6 to 18 months of age does not prevent linear growth faltering in Malawi. J Nutr. 145:1909–15.

Mangani C, Ashorn P, Maleta K, Phuka J, Thakwalakwa C, Dewey K, Manary M, Puumalainen T, Cheung YB. (2014) Lipid-based nutrient supplements do not affect the risk of malaria or respiratory morbidity in 6-to 18-month-old Malawian children in a randomized controlled trial. Am J Clin Nutr. 144:1835–42.

Marinda PA, Genschick S, Khayeka-Wandabwa C, Kiwanuka-Lubinda R, Thilsted SH. (2018) Dietary diversity determinants and contribution of fish to maternal and under-five nutritional status in Zambia. PLoS One. 13(9):e0204009. https://doi.org/10.1371/journal.pone.0204009 PMID: 30248126

Marquis, G. S., Colecraft, E. K., Kanlisi, R., Aidam, B. A., Atuobi-Yeboah, A. A., Pinto, C., & Aryeetey, R. (2018). An agriculture–nutrition intervention improved children's diet and growth in a randomized trial in Ghana. Maternal & Child Nutrition, 14(Suppl 3), 1–10. https://doi.org/10.1111/mcn.12677

Matias SL et al. (2017) *Process Evaluation of the Rang-Din Nutrition Study: Final Report.* Washington, DC: FHI 360/Food and Nutrition Technical Assistance III Project (FANTA).

Mbogah P, Nanua J, Ettyang G, Halimu S. (2020) The nexus between traditional food beliefs and nutritional status of children below two years: A case study of the Giriama in Kilifi County Kenya. *Afr. J. Med. Health Sci.* 32(3): 74–93. eISSN: 1022-9272

McLean, J, Northrup-Lyons, M, Reid, RJ, et al. (2019) From evidence to national scale: An implementation framework for micronutrient powders in Rwanda. *Matern Child Nutr*. 15:e12752. https://doi.org/10.1111/mcn.12752

Menon, P., Nguyen, P. H., Saha, K. L., Khaled, A., Sanghvi, T., Baker, J., … Rawat, R. (2016). Combining intensive counseling by frontline workers with a nationwide mass media campaign has large differential impacts on complementary feeding practices but not on child growth: Results of a cluster-randomized program evaluation in Bangladesh. The Journal of Nutrition, 146(10), 2075–2084. https://doi.org/10.3945/jn.116.232314

Mesfin A, Henry C, Girma M, Whiting SJ. (2015) Use of Pulse Crops in Complementary Feeding of 6-23-Month-Old Infants and Young Children in Taba Kebele, Damot Gale District, Southern Ethiopia. J Public Health Afr. 6(1):357. doi: 10.4081/jphia.2015.357. PMID: 28299132; PMCID: PMC5349259

Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, et al. (2009) Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. Food Nutr Bull. 30 (S3), S343–S404. https://doi.org/10.1177/15648265090303S303 PMID: 19998864

Michaux, K., et al. (2014) Home Fortification with Micronutrient Powders: Lessons learned from formative research across six countries, in Sight and Life, p. 26-32.

Mittermeier-Kleßinger VK, Hofmann T, Dawid C. (2021) Mitigating off-flavors of plant-based proteins. J Agric Food Chem. 69:9202–7. doi: 10.1021/acs.jafc.1c03398

Moore KJ, Warren MW, Davis DR, Johnson MG. (1988). Changes in bacterial cell and spore counts of reduced-fat egg products as influenced by pasteurization and spray drying. J Food Protect. 51:565–8. doi: 10.4315/0362-028X-51.

Morris, SS, Beesabathuni, K, Headey, D. (2018) An egg for everyone: Pathways to universal access to one of nature's most nutritious foods. *Matern Child Nutr*. 14(S3): e12679. https://doi.org/10.1111/mcn.12679

Moss, K., Dobson, A., Tooth, L., & Mishra, G. (2020). Associations between feeding practices in infancy and fruit and vegetable consumption in childhood. British Journal of Nutrition, 124(12), 1320-1328. doi:10.1017/S000711452000238X

Muhimbula HS, Issa-Zacharia A. (2010) Persistent child malnutrition in Tanzania: Risks associated with traditional complementary foods (A review). *Afr J Food Sci*. 4(11):679–692.

Mukuria, A.G., et al. (2016) Role of Social Support in Improving Infant Feeding Practices in Western Kenya: A Quasi-Experimental Study. Glob Health Sci Pract, 4(1): 55-72.

Mwangi MN, Dennis G A B Oonincx, Marijke Hummel, Dessy A Utami, Lidyawati Gunawan, Margot Veenenbos, Christophe Zeder, Colin I Cercamondi, Michael B Zimmermann, Joop J A van Loon, Marcel Dicke, Alida Melse-Boonstra. (2022). Absorption of iron from edible house crickets: a randomized crossover stable-isotope study in humans, American Journal of Clinical Nutrition 116 (4): 1146–1156. https://doi.org/10.1093/ajcn/nqac223

Nankumbi J, Muliira JK. (2015) Barriers to infant and child-feeding practices: a qualitative study of primary caregivers in Rural Uganda. J Health Popul Nutr. 33(1):106-16. PMID: 25995727; PMCID: PMC4438654.

Nguyen et al. (2011). A situational review of infant and young child feeding practices and interventions in Viet Nam. Asia Pac J Clin Nutr. 20(3): 359-74. PMID: 21859654.

Nguyen et al. (2019). Information Diffusion and Social Norms Are Associated with Infant and Young Child Feeding Practices in Bangladesh. Journal of Nutrition 149 (11): 2034–2045, https://doi.org/10.1093/jn/nxz167

Nkukwana, T.T. (2018) Global poultry production: Current impact and future outlook on the South African poultry industry. *S. Afr. J. Anim. Sci.* 48: 869–884.

Nutrition Reviews. (2021) Assessing nutrient gaps and affordability of complementary foods: new methods and their application in different settings. Nutrition Reviews, April 2021, Volume 79, Issue Supplement 1. https://academic.oup.com/nutritionreviews/issue/79/Supplement_1

Nyhus Dhillon C, Sarkar D, Klemm RD, et al. (2017) Executive summary for the Micronutrient Powders Consultation: Lessons Learned for Operational Guidance. *Matern Child Nutr*. 13Suppl 1(Suppl 1):e12493. 10.1111/mcn.12493.

Omueti, O., Otegbayo, B., Jaiyeola, O., & Afolabi, O. (2009). Functional properties of complementary diets developed from soybean (Glycine max), groundnut (Arachis hypogea) and crayfish (Macrobrachium spp). Electronic Journal of Environmental, Agricultural and Food Chemistry, 8(8).

Ortenzi F. and Beal T. (2021). Priority Micronutrient Density of Foods for Complementary Feeding of Young Children (6–23 Months) in South and Southeast Asia. *Front. Nutr*. 21 (8). https://doi.org/10.3389/fnut.2021.785227

Osei, A., et al. (2014) Using formative research to inform the design of a home fortification with micronutrient powders (MNP) Program in Aileu District, TimorLeste. Food Nutr Bull, 35(1): p. 68-82.

Pasqualino MM, Saijuddin Shaikh, John McGready, Md Tanvir Islam, Hasmot Ali, Tahmeed Ahmed, Keith P. West, Munirul Alam, Md Iqbal Hossain, Alain B. Labrique, Amanda C. Palmer. (2023) An Egg Intervention Improves Dietary Intakes but Does Not Fill Intake Gaps for Multiple Micronutrients among Infants in Rural Bangladesh. Journal of Nutrition, Volume 153, Issue 4, Pages 1199-1210, https://doi.org/10.1016/j.tjnut.2023.02.004.

Pelletier, D, DePee, S. (2019) Micronutrient powder programs: New findings and future directions for implementation science. *Matern Child Nutr*. 15(S5): e12802. https://doi.org/10.1111/mcn.12802

Perez-Escamilla, R., Bermudez, O., Buccini, G. S., et al. (2018). Nutrition disparities and the global burden of malnutrition. British Medical Journal, 361, k2252. https://doi.org/10.1136/bmj.k2252

Phuka JC, Maleta K, Thakwalakwa C, Cheung YB, Briend A, Manary MJ, Ashorn P. (2008) Complementary feeding with fortified spread and incidence of severe stunting in 6-to 18-month-old rural Malawians. Arch Pediatr Adolesc Med. 162:619–26.

Pirkwieser P, Grosshagauer S, Dunkel A, Pignitter M, Schneppe B, Kraemer K and Somoza V. (2022). Evaluation of spray-dried eggs as a micronutrient-rich nutritional supplement. Front. Nutr. 9:984715. doi: 10.3389/fnut.2022.984715

Prado EL, Adu-Afarwuah S, Lartey A, Ocansey M, Ashorn P, Vosti SA, Dewey KG. (2016a). Effects of pre- and post-natal lipid-based nutrient supplements on infant development in a randomized trial in Ghana. Early Hum Dev. 99:43–51.

Prado EL, Abbeddou S, Yakes Jimenez E, Somé JW, Ouédraogo ZP, Vosti SA, Dewey KG, Brown KH, Hess SY, Ouedraogo JB. (2016b). Lipid-based nutrient supplements plus malaria and diarrhea treatment increase infant development scores in a randomized trial in Burkina Faso. J Nutr. 146:814–22.

Prado EL, Phuka J, Maleta K, Ashorn P, Ashorn U, Vosti SA, Dewey KG. (2016c). Provision of lipid-based nutrient supplements from age 6 to 18 months does not affect infant development scores in a randomized trial in Malawi. Matern Child Health J. 10:2199–08.

Prado, E.L. et al. (2021) Small-quantity lipid-based nutrient supplements for children age 6-24 months: a systematic review and individual participant data meta-analysis of effects on developmental outcomes and effect modifiers. Am J Clin Nutr. 114(Suppl 1):43S-67S. doi: 10.1093/ajcn/nqab277. PMID: 34590116; PMCID: PMC8560311.

Rapson, J.P., von Hurst, P.R., Hetherington, M.M. et al. (2021). Impact of a "vegetables first" approach to complementary feeding on later intake and liking of vegetables in infants: a study protocol for a randomised controlled trial. *Trials* 22, 488. https://doi.org/10.1186/s13063-021-05374-7

Rapson JP, et al. (2022). Starting complementary feeding with vegetables only increases vegetable acceptance at 9 months: a randomized controlled trial. *American Journal of Clinical Nutrition* 116 (1): 111–121. https://doi.org/10.1093/ajcn/nqac080

Rasheed S et al. (2011). Why does nutrition deteriorate rapidly among children under 2 years of age? Using qualitative methods to understand community perspectives on complementary feeding practices in Bangladesh. Food Nutr Bull. doi: 10.1177/156482651103200302. PMID: 22073792.

Rawal V, Charrondiere R, Xipsiti M, and Grande F. (2019). Pulses: nutritional benefits and consumption patterns. Rawal V, Navarro DK (Eds). The Global Economy of Pulses, FAO., Rome, pp. 9-19.

Rawat R et al. (2017). Social franchising and a nationwide mass media campaign increased the prevalence of adequate complementary feeding in Vietnam: a cluster-randomized program evaluation. J Nutr 2017;147:670–9.

Réhault-Godbert S, Guyot N, Nys Y. (2019) The Golden Egg: Nutritional Value, Bioactivities, and Emerging Benefits for Human Health. Nutrients. 11(3):684. doi: 10.3390/nu11030684. PMID: 30909449; PMCID: PMC6470839.

Roos, N., Wahab, M. A., Chamnan, C., & Thilsted, S. H. (2007). The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. Journal of Nutrition, 137, 1106–1109.

Roschnik, N., Diarra, H., Dicko, Y., Diarra, S., Stanley, I., Moestue, H., … Clarke, S. (2019). Adherence and acceptability of community-based distribution of micronutrient powders in Southern Mali. Maternal and Child Nutrition, 15(Suppl. 5), e12831. https://doi.org/10.1111/mcn.12831

Ruel MT, Menon P. (2002) Child feeding practices are associated with child nutritional status in Latin America: innovative uses of the demographic and health surveys. *J Nutr.* 132:1180–7.

Ryckman et al. (2021). Affordability of nutritious foods for complementary feeding in Eastern and Southern Africa. https://doi.org/10.1093/nutrit/nuaa137

Sarrassat S. et al. (2019). Suboptimal infant and young child feeding practices in rural Boucle du Mouhoun, Burkina Faso: Findings from a cross-sectional population-based survey. PLoS ONE 14(11): e0224769. https://doi.org/10.1371/journal.pone.0224769

Schmied, V. et al. (2020). Feeding My Child: How mothers experience nutrition across the world. A Companion Report to The State of the World's Children 2019. Sydney: Western Sydney University and United Nations Children's Fund (UNICEF). DOI: 10.26183/5597-mw05 (https://doi.org/10.26183/5597-mw05)

Semba, R. D., Ramsing, R., Rahman, N., Kraemer, K., & Bloem, M. W. (2021). Legumes as a sustainable source of protein in human diets. *Global Food Security*, *28*, 100520. https://doi.org/10.1016/j.gfs.2021.100520

Sibhatu, K.T., Qaim, M. (2018). Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. Food Policy, 77, 1–18. https://doi.org/10.1016/j. foodpol.2018.04.013

Siekmans, K., et al. (2017) The potential role of micronutrient powders to improve complementary feeding practices. Matern Child Nutr, 13 Suppl 2.

Sight and Life. (2023a) EggHub: Evidence – Science. https://egghub.org/science

Sight and Life. (2023b) Egg Hub: Evidence – Supply. https://egghub.org/supply

Simoons, F. J. (1994). Eat not this flesh. In Food avoidances from prehistory to the present, 2nd ed. Madison, Wisconsin: University of Wisconsin Press.

Smith, L., López Sánchez, G.F., Veronese, N. et al. (2022) Fruit and Vegetable Intake and Non-Communicable Diseases among Adults Aged ≥50 Years in Low- and Middle-Income Countries. *J Nutr Health Aging* 26, 1003–1009. https://doi.org/10.1007/s12603-022-1855-z

Soman D, Zhao M. (2011) The fewer the better: Number of goals and savings behavior. *J Marketing Res*. 48(6):944–957.

Stewart CP, Iannotti L, Dewey KG, Michaelsen KF, Onyango AW. (2013) Contextualising complementary feeding in a broader framework for stunting prevention. *Matern Child Nutr*. 9(suppl 2):27–45.

Stewart CP, Bess Caswell, Lora Iannotti, Chessa Lutter, Charles D Arnold, Raphael Chipatala, Elizabeth L Prado, Kenneth Maleta. (2019) The effect of eggs on early child growth in rural Malawi: the Mazira Project randomized controlled trial. *American Journal of Clinical Nutrition*, Volume 110, Issue 4: 1026–1033. https://doi.org/10.1093/ajcn/nqz163

Stewart CP, Wessells KR, Arnold CD, Huybregts L, Ashorn P, Becquey E, Humphrey JH, Dewey KG. (2020) Lipid-based nutrient supplements and all-cause mortality in children 6-24 months of age: a meta-analysis of randomized controlled trials. Am J Clin Nutr. 111(1):207-218. doi: 10.1093/ajcn/nqz262. PMID: 31697329.

Suchdev, P.S., Jefferds, M.E.D., Ota, E., da Silva Lopes, K. & De-Regil, L. M. (2020). Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age. Cochrane Database Syst. Rev. https://doi.org/10.1002/14651858.CD008959.pub3 (2020).

Sutrisna, A., Vossenaar, M., Poonawala, A., Mallipu, A., Izwardy, D., Menon, R., & Tumilowicz, A. (2018). Improved information and educational messages on outer packaging of micronutrient powders distributed in Indonesia increase caregiver knowledge and adherence to recommended use. Nutrients, 10(6), 747. https://doi.org/10.3390/nu10060747

Teshome GB, Whiting SJ, Green TJ, Mulualem D, Henry CJ. (2020) Scaled-up nutrition education on pulse-cereal complementary food practice in Ethiopia: a cluster-randomized trial. BMC Public Health. 20(1):1437. doi: 10.1186/s12889-020-09262-8. PMID: 32962685; PMCID: PMC7507676.

Thacher TD, Bommersbach TJ, Pettifor JM, Isichei CO, Fischer PR. (2015) Comparison of Limestone and Ground Fish for Treatment of Nutritional Rickets in Children in Nigeria. J Pediatr. 167(1):148-54.e1. doi: 10.1016/j.jpeds.2015.02.008. Epub 2015 Mar 19. PMID: 25799193.

Touré O, Coulibaly S, Arby A, Maiga F, Cairncross S. (2013) Piloting an intervention to improve microbiological food safety in Peri-Urban Mali. *Int J Hyg Environ Health*. 216(2):138–145.

Tumilowicz, A., Habicht, J. P., Mbuya, M. N. N., Beal, T., Ntozini, R., Rohner, F., … Neufeld, L. M. (2019a). Bottlenecks and predictors of coverage and adherence outcomes for a micronutrient powder program in Ethiopia. Maternal & Child Nutrition, 15(Suppl. 5), e12807. https://doi.org/10.1111/mcn.12807

Tumilowicz, A., Vossenaar, M., Kjaer, K., Vettersand, J., Possolo, E., Pelto, G. H., Jefferds, M. E., Norte, A., Dias, S., Osman, N., Gonzalez, W., Poonawala, A., & Neufeld, L. M. (2019b). Mixed methods evaluation explains bypassing of vouchers in micronutrient powder trial in Mozambique. *Maternal & Child Nutrition*, *15*(Suppl 5). https://doi.org/10.1111/mcn.12718

Unger SA, Drammeh S, Hasan J, Ceesay K, Sinjanka E, Beyai S, Sonko B, Dondeh BL, Fulford AJ, Moore SE et al. (2017) Impact of fortified versus unfortified lipid-based supplements on morbidity and nutritional status: a randomised double-blind placebo-controlled trial in ill Gambian children. PLoS Med. 14(8):e1002377.

UNICEF (United Nations Children's Fund). (2020a) Improving Young Children's Diets During the Complementary Feeding Period. UNICEF Programming Guidance. UNICEF, New York

UNICEF. (2020b). Regional landscape analysis of trends and drivers and determinants of young children's diets in Latin America and the Caribbean. UNICEF

UNICEF. (2020c). Regional report on maternal nutrition and complementary feeding.

UNICEF. (2021a) Fed to Fail? The Crisis of Children's Diets in Early Life. Brief. 2021 Child Nutrition Report. UNICEF, New York

UNICEF. (2021b) Multiple Micronutrient Powder Supply and Market Update. UNICEF Supply Division. New York. https://www.unicef.org/supply/media/566/file/Multiple-Micronutrient-Power-Market-Note-July-2021.pdf.

UNICEF. (2023) Small Supplements for the Prevention of Malnutrition in Early Childhood (Small Quantity Lipid-based Nutrient Supplements) Brief Guidance Note. https://www.unicef.org/media/134786/file/SQLNS_Brief_Guidance_Note.pdf

UNICEF United Kingdom. (2016) Responsive Feeding: Supporting Close and Loving Relationships. https://www.unicef.org.uk/babyfriendly/wp-content/uploads/sites/2/2017/12/Responsive-Feeding-Infosheet-Unicef-UK-Baby-Friendly-Initiative.pdf

UNICEF and GAIN (Global Alliance for Improved Nutrition). (2019). Food systems for children and adolescents: Working together to secure nutritious diets. UNICEF, New York.

University of California, Davis. (2023). Small-Quantity Lipid-Base Nutrient Supplements FAQs. https://sqlns.ucdavis.edu/FAQs

UN-Nutrition. (2021). The role of aquatic foods in sustainable healthy diets. Rome.

USAID Advancing Nutrition. (2022) Small-Quantity Lipid-Based Nutrient Supplement Program Implementation Learnings and Considerations for Scale-Up from International Food Relief Partnership Partners in Honduras, Niger, and Somalia. Arlington, VA: USAID Advancing Nutrition.

Van Huis, A. (2016) Edible insects are the future? Proc. Nutr. Soc., 75 (2016), pp. 294-305. https://doi:10.1017/S0029665116000069

Vossenaar, M, Tumilowicz, A, D'Agostino, A, et al. (2017) Experiences and lessons learned for programme improvement of micronutrient powders interventions. *Matern Child Nutr*. 13(S1): e12496. https://doi.org/10.1111/mcn.12496

Wallace TC, Rohloff P, Jimenez EY, Proaño GV, Montenegro-Bethancourt G, McCabe GP, Steiber A. (2022) Academy of Nutrition and Dietetics Nutrition Research Network: The Saqmolo' Project Rationale and Study Protocol for a Randomized Controlled Trial Examining the Influence of Daily Complementary Feeding of Eggs on Infant Development and Growth in Guatemala. J Acad Nutr Diet. 122(2):432-444. doi: 10.1016/j.jand.2021.03.015. Epub 2021 May 4. PMID: 33962902.

Warren AM, Frongillo EA, Rawat R. (2020) Building Implementation Science in Nutrition. Adv Nutr. 11(5):1392-1398. doi: 10.1093/advances/nmaa066. PMID: 32583850; PMCID: PMC7490173.

Webb P, et al. (2021). Global Nutrition and Policy Consortium. Modelling the potential cost-effectiveness of food-based programs to reduce malnutrition. Glob Food Sec. 2021 Jun;29:100550. doi: 10.1016/j.gfs.2021.100550. PMID: 34164258; PMCID: PMC8202230.

Werner R, Charles D Arnold, Bess L Caswell, Lora L Iannotti, Chessa K Lutter, Kenneth M Maleta, Christine P Stewart. (2022a) The Effects of 1 Egg per Day on Iron and Anemia Status among Young Malawian Children: A Secondary Analysis of a Randomized Controlled Trial. Current Developments in Nutrition 6 (6): nzac094, https://doi.org/10.1093/cdn/nzac094

Werner, R, Caswell B, Arnold C, Iannotti L, Maleta K, and Stewart C. (2022b) Frequency of Small Fish Consumption Is Associated With Improved Iron and Hemoglobin in Young Malawian Children. Current Developments in Nutrition 6 (Supplement 1): 615, https://doi.org/10.1093/cdn/nzac060.073

Wessells, K.R. et al. (2021) Characteristics that modify the effect of small-quantity lipid-based nutrient supplementation on child anemia and micronutrient status: an individual participant data meta-analysis of randomized controlled trials. Am J Clin Nutr. 2021 Nov 2;114(Suppl 1):68S-94S. doi: 10.1093/ajcn/nqab276. PMID: 34590114; PMCID: PMC8560313.

WFP (World Food Programme). (2016) Technical specifications for micronutrient powder – children 6-59 months. https://documents.wfp.org/stellent/groups/public/documents/manual_guide_proced/wfp284911.pdf

White et al. (2021). Micronutrient gaps during the complementary feeding period in 6 countries in Eastern and Southern Africa: a CONGA. https://doi.org/10.1093/nutrit/nuaa142

WHO. (2012) Guiding Principles for Complementary Feeding of the Breastfed Child. https://paho.org/hq/dmdocuments/2012/GuidingPrinciples.pdf

WHO. (2016). WHO Guideline: Use of Multiple Micronutrient Powders for Point-of-Use Fortification of Foods Consumed by Infants and Young Children Aged 6-23 Months and Children Aged 2-12 Years. Geneva: World Health Organization.

Zlotkin SH, Schauer C, Christofides A, Sharieff W, Tondeur MC, Hyder SMZ. (2005) Micronutrient sprinkles to control childhood anaemia. A simple powdered sachet may be the key to addressing a global problem. PLoS Medicine 2: e10. Available at: www.plosmedicine.org.