Current and potential role of specially formulated foods and food supplements for preventing malnutrition among 6- to 23-month-old children and for treating moderate malnutrition among 6- to 59-month-old children

Saskia de Pee and Martin W. Bloem

Abstract

Reducing child malnutrition requires nutritious food, breastfeeding, improved hygiene, health services, and (prenatal) care. Poverty and food insecurity seriously constrain the accessibility of nutritious diets that have high protein quality, adequate micronutrient content and bioavailability, macrominerals and essential fatty acids, low antinutrient content, and high nutrient density. Diets based largely on plant sources with few animal-source and fortified foods do not meet these requirements and need to be improved by processing (dehulling, germinating, fermenting), fortification, and adding animal-source foods, e.g., milk, or other specific nutrients. Options include using specially formulated foods (fortified blended foods, commercial infant cereals, or ready-to-use foods [RUFs; pastes, compressed bars, or biscuits]) or complementary food supplements (micronutrient powders or powdered complementary food supplements containing micronutrients, protein, amino acids, and/or enzymes or lipid-based nutrient supplements (120 to 250 kcal/day), typically containing milk powder, high-quality vegetable oil, peanut paste, sugar, and micronutrients. Most supplementary feeding programs for moderately malnourished children supply fortified blended foods, such as corn–soy blend, with oil and sugar, which have shortcomings, including too many antinutrients, no milk (important for growth), suboptimal micronutrient content, high bulk, and high viscosity. Thus, for feeding young or malnourished children, fortified blended foods need to be improved or replaced. Based on success with ready-to-use therapeutic foods (RUTFs) for treating severe acute malnutrition, modifying these recipes is also considered. Commodities for reducing child malnutrition should be chosen on the basis of nutritional needs, program circumstances, availability of commodities, and likelihood of impact. Data are urgently required to compare the impact of new or modified commodities with that of current fortified blended foods and of RUTF developed for treating severe acute malnutrition.

Key words: Child malnutrition, complementary food supplements, corn–soy blend, fortified blended foods, micronutrient powder, ready-to-use foods, RUTF, supplementary feeding

Introduction

The treatment of malnutrition, as well as its prevention, among children under 5 years of age requires consumption of nutritious food, including exclusive breastfeeding for the first 6 months of life, followed by breastfeeding in combination with complementary foods thereafter until at least 24 months of age; a hygienic environment (clean drinking water, sanitary facilities); access to preventive (immunization, vitamin A supplementation, etc.) as well as curative health services, and good prenatal care.

In this article, the focus is on possible options for providing a nutritious diet, realizing the constraints faced by many people whose children are at risk for developing or confirmed to be suffering from moderate malnutrition (stunting as well as wasting), such as poverty and food insecurity. Although the nutrient density requirements proposed by Golden [1] are for moderately malnourished children, much of the

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dietary recommendations and complementary food supplements proposed for improving dietary quality are also relevant for young children (6 to 23 months) at risk for developing moderate malnutrition, i.e., among populations with a high prevalence of stunting among children 2 to 5 years of age and wasting among those 6 to 59 months of age. Therefore, much of the discussion in this article is applicable to young (6 to 23 months) and growth-faltering children as well as to moderately malnourished children (wasted children with weight-for-height < −2 and ≥ −3 z-scores or stunted children with height-for-age < −2 z-scores).

We will also cover a range of interventions, from food-assistance programs for people who are wholly dependent on food assistance (refugees, people affected by man-made or disaster-related emergencies) and populations requiring food assistance during lean or bad harvest periods, to populations that are not typically food insecure but consume a relatively monotonous diet with too few good-quality foods to provide vulnerable groups with the required intake of specific essential nutrients (such as micronutrients, macrominerals, essential amino acids, and essential fatty acids).

This article starts with a discussion of options for dietary improvement, modification possibilities for ready-to-use therapeutic foods (RUTFs), improvement of fortified blended foods, and different kinds, roles, limitations, and applications of complementary food supplements. These considerations are then compared with current practices in programs treating moderately wasted children as reported in response to a questionnaire that was sent out by Anne Ashworth and Saskia de Pee between February and August 2008. This assessment of current practices is then followed by programmatic considerations for expansion of the use of new food supplement products for preventing and treating moderate malnutrition among young children.

This article complements the articles in this issue by Golden [1], Michaelsen et al. [2], and Ashworth and Ferguson [3], with Golden having established the nutrient requirements, Michaelsen et al. having reviewed the value and limitations of specific foods and food groups, based on their content of nutrients and antinutrients, and Ashworth and Ferguson having assessed the adequacy of dietary recommendations for moderately malnourished children using locally available foods in relatively food-secure but poor households.

Option 1. Local diet: Required food groups and options for improving nutrient adequacy

Among relatively food-secure populations (i.e., those with adequate energy intake per capita), the primary approach to prevent and treat malnutrition is by providing dietary advice about which foods to consume. Such advice is characterized by emphasis on consumption from all food groups (anywhere between four and eight groups are distinguished), changing the kinds of foods chosen from these food groups (thus, for example, to alternate plant and animal sources of protein), frequent and responsive feeding, and ensuring good energy density [3–5]. The article by Ashworth and Ferguson in this supplement [3] assesses whether and how nutrient requirements proposed for moderately malnourished children can be met by selecting locally available foods and examines the evidence for an impact of diets and programs based on promotion of locally available foods.

Table 1 shows the nutrient groups and active compounds that are essential for good child growth and development together with the main dietary sources of these nutrients and compounds and comments on the consumption of these foods. In summary, a relatively wide variety of foods is required, including breastmilk, staples (for energy and some micronutrients), legumes or lentils (particularly for protein), animal-source foods (good sources of protein, minerals, and some vitamins), vegetables and fruits (for vitamins, minerals, and vitamin C to enhance absorption of nonheme iron), oil (for energy and essential fatty acids), and a source of iodine such as salt (but note that a high sodium intake in moderately malnourished children is not desirable). **Table 2** shows the important characteristics of diets for young malnourished children (adapted from the article by Michaelsen et al. [2]) and considerations with regard to foods required to realize consumption of such diets.

However, as one respondent to the questionnaire on current programs (see below) said:

> …very often the causes of malnutrition are attributable to wide-scale food insecurity.… In such instances, there is simply no choice of food at household level, lack of variety and high market prices create inaccessibility to a diversity of foods, in addition to exhausted household assets with which to purchase or barter and as such, people are often reported to be living off a single staple.… During such times, diet diversity cannot be promoted, so education will focus on the importance of personal hygiene and household sanitation, appropriate breast feeding and timely complementary feeding practices.

Where the diet consists largely of plant foods with very few animal-source foods and fortified foods,* as is the case for many children and their families in developing countries, there are a number of issues to be addressed. As can be concluded from **tables 1** and **2**, plant foods, especially staples (maize, wheat, rice), legumes, lentils, and vegetables, contain considerable

* Typical fortified foods that tend to be available in developing-country markets are fortified flour, fortified noodles, fortified margarine, fortified milk (powder), and fortified complementary foods.

TABLE 1. Essential nutrients and active compounds and their dietary sources, including recommended home processing where applicable

Nutrients and active compounds of concern	Dietary sources	Comments
Vitamins, plant origin	Vegetables and fruits, grains	Bioavailability (due to antinutrient content of plant foods) as well as absolute quantity of foods to be consumed is of concern
Minerals	Animal-source foods and plant foods	When largely relying on plant foods, intake has to be high (can, for example, be increased by using a dried leaf concentrate), and bioavailability has to be improved, particularly by reducing contents of phytate and polyphenols and/or adding vitamin C. For example, bioavailability of iron is much higher from meat than from vegetables (25% vs. 2%–10%) [6]
Vitamins, animal origin (especially vitamin B_6, vitamin B_{12}, retinol)	Breastmilk, animal milk, organ meat, red meat, poultry, fish, eggs, butter (retinol)	No single animal-source food provides all the MNs that are required from animal-source foods in adequate amounts.[a] Thus, a variety of animal-source foods is required
Iodine	Seafood, including algae, and iodized salt	The use of iodized salt contributes greatly to the prevention of iodine-deficiency disorders (approximately 70% of the world's households are covered)
Proteins, to result in a diet with high PDCAAS score	Soybeans, peanuts, legumes, breastmilk, animal milk, organ meat, red meat, poultry, fish, eggs	Same comment as for vitamins from animal-source foods. A mixture of foods is required to ensure adequate intake of all essential amino acids. Plant sources of protein also have a relatively high content of antinutrients, which affects absorption of minerals
Essential fatty acids, especially those with a favorable n-6:n-3 ratio (~ 6)	Fatty fish or their products, soybean oil, rapeseed oil (also known as canola oil)	Only fatty fish and a few oils have a favorable fatty acid profile, and these are not generally consumed in large amounts in most developing-country diets
Growth factor from milk[b]	Dairy products (breastmilk, animal milk, yogurt, cheese)	Skimmed-milk powder when reconstituted with water is not appropriate for young children because of the lack of fat. Full-cream milk powder is usually skimmed-milk powder to which powdered vegetable fat has been added. When reconstituted with clean, safe water, this is good milk for children. Cheese is not recommended for feeding young malnourished children [2]
Phytase, α-amylase	Present in grains themselves, released when germinating (requires soaking for 24 h), malting (i.e., when germinating or adding malt), or fermenting	These processes require modification of food processing as well as use of whole grains rather than purchased flour. Also, the impact of these food-processing technologies on improving mineral bioavailability and MN status has not been shown to be substantial enough to markedly reduce MN deficiencies

MN, micronutrient; PDCAAS, protein digestibility-corrected amino acid score

a. Even breastmilk is a poor source of certain micronutrients. When a child is born with adequate stores, these stores, in combination with exclusive breastmilk consumption for the first 6 months of life from an adequately nourished mother, will ensure that all needs are met. Introducing complementary foods early reduces the bioavailability of some micronutrients, particularly minerals, from breastmilk and could thus increase the risk of deficiencies when the complementary foods are not of appropriate composition. Children born prematurely or with low birthweight need micronutrient supplements, in addition to exclusive breastmilk consumption, from approximately 2 months of age.

b. The presence of factors in milk (peptides or non-phytate-bound phosphorus that promote growth is very likely but not fully proven as yet) [7, 8].

amounts of antinutrients (such as phytate, polyphenols, lectins, and inhibitors of protease and α-amylase), which reduce mineral bioavailability and interfere with digestion of specific compounds. Therefore, special processing to reduce the content of antinutrients should be used, the content of vitamins and minerals should be increased in order to compensate for the lower bioavailability, or both. Furthermore, oil or sugar should be added to increase energy density.

Figure 1 summarizes options for improving nutritional quality of a largely plant-source based diet when adding animal source foods and fortified foods

TABLE 2. Important characteristics of diets appropriate for young children to prevent and treat moderate malnutrition and considerations

Important characteristics[a]	Considerations
High content of MNs, especially type II nutrients	Calcium, phosphorus, magnesium, and potassium are nutrients that are not contained in most MN formulations such as MN powders and are required in larger amounts (hundreds of milligrams instead of < 10 mg)
High energy density	Fat and sugar increase energy content with minimum increase of volume, but adequate MN content/1,000 kcal of diet or meal needs to be ensured
Adequate protein content High protein quality and availability	Requires mixture of legumes, lentils, and animal-source foods
Low content of antinutrients	Requires processing of staples, legumes, and lentils, industrially or at household level
Adequate fat content Appropriate fat quality, especially n-3/n-6 PUFA content	Requires consumption of 30–40 energy % from fat contributed by foods that have the right fatty acid composition — i.e., fatty fish or its products (fish oil), or soybean, rapeseed, or canola oil
Acceptability: taste, texture, and cultural acceptability	As much as possible, use locally available foods
Easy to prepare	The processing of plant foods to reduce antinutrient content should be done industrially, where (especially urban) populations have good access to such foods, because these are time-consuming and more and more people are switching to use of convenient-to-prepare foods
Affordable	Poverty is the main reason why many children lack an adequate amount of animal-source and fortified foods in their diet Affordable, fortified, processed foods as well as subsidized and for-free distribution options need to be developed
Low risk of contamination	Food-production and food-processing standards need to ensure low risks of microbes, toxins, and contaminants

MN, micronutrient; PUFA, polyunsaturated fatty acid
a. Source: adapted from Michaelsen et al. [2].

in adequate amounts is not feasible, due to cost or availability issues. The options are divided into procedures that can be performed at home and those that are performed during industrial processing of foods. Home procedures consist of processing and preparation practices using only locally available, unprocessed foods (germination, soaking, or fermenting to reduce antinutrient contents and increase bioavailability, as well as preservation of plant-source foods to increase intake of the micronutrients they can provide) or addition of those nutrients that are lacking through the use of complementary food supplements (i.e., home fortification or point-of-use fortification).

Home-fortification options are discussed in greater detail below (Option 4: Complementary Food Supplements). Very little information is available on the effectiveness of home-processing steps to reduce antinutrient content for increasing mineral bioavailability (which has been the main focus) [2, 9]. For industrial processes, including the use of enzymes, more information is available about their impact [10–12], but none has been implemented at scale for human consumption, for various reasons. However, the recent increase of commitment to reducing child malnutrition and increased understanding of what nutrients and foods are required has also stimulated interest and research and development efforts on the part of food manufacturers to process foods and produce active ingredients for inclusion in special foods or for use in food preparation.

Option 2. Modifying RUTFs for maximizing catch-up growth among moderately malnourished children

We now move from populations with food security but limited access to quality foods to populations facing food insecurity and a high prevalence of child malnutrition, including severe wasting. It is in these populations that RUTFs for treatment of children suffering from severe acute malnutrition used in Community-Based Management of Severe Acute Malnutrition (CMAM) programs are increasingly making a difference to child survival [13–16], and the question has arisen about what foods to provide to moderately malnourished children.

Children suffering from severe acute malnutrition who are being rehabilitated go through a phase of moderate malnutrition before reaching the discharge criteria of having gained adequate weight. Thus, RUTF provides all the nutrients required to promote growth and health among children with severe acute malnutrition and could therefore also, in principle, be considered for treating moderately malnourished children. In fact, its effectiveness for such use has been shown in a study in Malawi [17] as well as in a program in Niger [18].

However, RUTF probably provides nutrients in excess of what moderately malnourished children need, and providing RUTF is not realistic for the vast majority of identified children with moderate malnutrition, due to the limited production capacity of this special product,* ** the cost of the product, and the acceptability of the product where peanuts (an important ingredient) are not commonly consumed. Because of this, efforts are being undertaken to modify the RUTF recipe so that costs are lower and more locally available ingredients are used. **Figure 2** illustrates some of the options that can be considered when trying to modify the RUTF recipe. When just the nutrient content of RUTF is considered, quite a number of options exist for exchange of ingredients. However, when antinutrient content, palatability, processing, storage, and packaging are also considered, the options become more limited.

Four products for moderately malnourished children that are basically modifications of the RUTF recipe have been identified so far, as follows:

» Supplementary Plumpy produced by Nutriset, France. In this product, the skimmed-milk powder of RUTF (Plumpy'Nut) has been replaced with whey and soy protein isolates*** to reduce costs (see **tables 3** and **4**, last categories of products). Otherwise, the ingredients and nutrient contents are the same as those of RUTF. The product is being used in a few programs and in operational studies that assess its impact on linear growth, weight gain, and length of stay in the program among moderately wasted children.

» Project Peanut Butter in Malawi produces a peanut/soybean paste from 25% whole roasted soybean (not dehulled), 20% soybean oil, 26% peanut paste, 27% sugar, and 2% micronutrients (providing 1 RDA per daily dose of 125 g). This product was compared with fortified blended food with additional fish powder, and no difference in linear growth was observed [21]. The absence of milk in the spread and the addition of fish powder to the fortified blended food may explain this absence of difference. Studies are also being done with spreads that include milk powder comparing these spreads with fortified blended food (Likuni Phala). A recent study suggests that such a spread (at 25 or 50 g/day) has a greater impact than fortified blended food on severe stunting but not on weight gain [22]. However, another study that compared milk/peanut spread, soybean/peanut spread, and corn–soy blend found that recovery from moderate wasting was higher in both groups receiving spreads than in the group receiving corn–soy blend (80% vs. 72% recovery) [23].

» Indian RUFC (Ready-to-Use Food for Children) has been developed by WFP India and includes chickpeas, rice flour, a higher amount of oil to replace peanuts, and less skimmed-milk powder to reduce costs. Because chickpeas contain more antinutrients than peanuts and because the milk content has been reduced from 30% in RUTF to 10% in Indian RUFC, the impact on growth and micronutrient status of moderately malnourished children needs to be assessed.

» A baked biscuit has been developed by a consortium of German and Indonesian universities in collaboration with Church World Service that consists of wheat flour, peanut paste, soybeans, oil, sugar, and micronutrient premix and is locally produced in Indonesia. This product also has a higher antinutrient content than RUTF because of the inclusion of wheat flour and soybeans and probably has less impact on linear growth because of the absence of milk.

Although the last three products are likely to be less effective than RUTF, they are presumably better than fortified blended food, the main product that is currently provided to children with moderate acute malnourishment (see sections below on Current Programs for Moderately Malnourished Children and Ready-to-Use Foods vs. To-Be-Prepared Foods: Storage and Preparation).

Option 3. Fortified blended foods: Current composition and improvement options

Fortified blended foods, such as corn–soy blend and

* The anticipated production capacity of ready-to-use food (RUF) by the Plumpy'field Network of Nutriset, the main producers of RUTF, by the end of 2010 is 63,800 metric tons, [Mamane Zeilani, Scaling up Production of RUF, International Workshop on the Integration of CMAM. FANTA/AED/Washington. 28-30 April 2008, Washington, DC (http://www.fantaproject.org/downloads/pdfs/D3.S8.Zeilani.pdf], which is sufficient to treat 5.3 million of the 19 million children under 5 years of age suffering from severe acute malnutrition worldwide. Of the total anticipated production, 77% will be produced in France and the remaining 23% in 10 countries across Central America, Africa, and the Middle East (300 to 3,000 metric tons/year at each location). The products will include RUTF (Plumpy'Nut) and its related RUF products (Supplementary Plumpy, Plumpy'Doz, and Nutributter). By the end of 2011, production capacity will have reached 100,000 metric tons/year (Mamane Zeilani, personal communication, September 2008).

** At present (December 2008), manufacturers of RUF include Compact, Hilina, Nutriset, Project Peanut Butter, STA, and Valid Nutrition.

*** Earlier versions of Supplementary Plumpy had a somewhat different formulation.

<table>
<tr><th>Local diet: Issues</th><th colspan="2">Modification options</th></tr>
<tr><td rowspan="2">Not enough of
• MNs (cause: low intake of animal-source and fortified foods and low bioavailability)
• n-3 PUFAs
• Essential amino acids</td><td colspan="2">Home fortification to correct too low nutrient intake
• Add MNs (MN powder, lipid-based nutrient supplement, MN-fortified protein powder or dried leaf concentrate [but has limited content of vitamins found in animal-source foods])
• Add n-3 PUFAs (soybean oil [alpha-linolenic acid or ALA], fish oil [docosahexaenoic acid or DHA], separate or added to home fortificant such as lipid-based nutrient supplements)
• Add protein extract or add amino acids, such as lysine, to home fortificant (MN-fortified protein powder or lipid-based nutrient supplement)</td></tr>
<tr><td>Processing of food — at home
• Soaking, germination, malting; requires whole grain (i.e., not applicable to flour) and time
• Fermentation; specific practice for specific foods, not too easy to introduce</td><td rowspan="3">Adding enzymes, when industrially processing food or at home, to reduce phytate content, by
• Soaking fortified blended food ingredients together with phytase, before extrusion cooking and drying; requires equipment (conditioner and dryer)
• Adding phytase to the processed product (note: needs time to act once food has been prepared)
• Adding phytase to prepared product (i.e., home fortification)
Note: Last two options require approval for young human use and a different phytase because of different temperature and pH (see also footnote to fig. 3).
• Using germinated flour for making porridge, as it will then be less thick and have less phytate
• Adding malt to the prepared product (home fortification) to reduce viscosity and phytate content</td></tr>
<tr><td>Too much of
• Phytate (binding minerals, including phosphorus)
• Other antinutrients such as polyphenols, trypsin inhibitors</td><td rowspan="2">Processing of food — industrial
• Roasting, milling, extrusion cooking are normally done but do not have enough impact on phytate content
• Dehulling, degerming; requires specific equipment and results in up to 25%–35% of product being discarded/requiring alternative use (animal feed?) and cost implications
• Malting (as occurs in germination) produces phytase and α-amylase, which reduces phytate content and converts starch into sugars. Using germinated flour for porridge also makes it less thick so that children can consume more
Note: The latter two processes are not normally done</td></tr>
<tr><td rowspan="2">Other issues
• Low energy density in watery porridges
• Bulk and viscosity are limiting intake</td></tr>
<tr><td colspan="2">Increasing energy density
• Adding oil and sugar will increase energy density without increasing volume very much. However, sugar should be added in limited amounts, and adequate micronutrient density (/1,000 kcal) should be ensured</td></tr>
</table>

FIG. 1. Options to modify the currently prevailing local diet, largely consisting of plant foods, to treat moderate malnutrition among children under 5 years of age or prevent it among young children (6–23 mo) where intake of animal-source and fortified foods is limited due to access (affordability and availability) constraints. MN, micronutrient; PUFA, polyunsaturated fatty acid

wheat–soy blend, have been provided as one of the only fortified food-assistance commodities among many different populations, and for a wide range of purposes, for the past 30 years or more. They consist of 20% to 25% soybeans, 75% to 80% corn or wheat, and a micronutrient premix. Because of the protein content and quality (total protein digestibility-corrected amino acid score [PDCAAS] of corn–soy blend: 65%) from the soybeans and the additional micronutrients, fortified blended foods have been regarded as being of reasonably good nutritional value for limited cost and are being produced in more than 20 countries around the globe. Fortified blended foods also became the products of choice from the few nonperishable food items used in food-assistance programs* to be provided to moderately malnourished children as well as other vulnerable groups (pregnant and lactating women and people chronically ill with HIV/AIDS or tuberculosis). In 2007, WFP distributed 242,000 metric tons of fortified blended foods, including 192,000 metric tons of corn–soy blend, to specific groups as well as to general populations because of the micronutrient and protein contents.

* Items included in the food basket used in food-assistance programs typically include staples (whole grains of rice, wheat, and/or corn, or flour in the case of wheat and corn; flour has a shorter shelf-life than whole grains but can, and should, be fortified), pulses (grams, lentils), cooking oil (fortified with vitamin A), iodized salt, and fortified blended foods (the main source of micronutrients unless fortified flour is part of the food basket).

RUTF		Steps to be explored for reducing costs and increasing local production		
Positive • Shown to promote growth very well • Can be safely stored and used in communities and households	**Negative** • Production capacity not enough to also treat moderate acute malnutrition • Costs of ingredients are high, especially milk • Peanut taste is not familiar in certain parts of the world (e.g., South Asia), and in those places peanut availability is also limited	**Modify from…** • 30% full-fat milk powder • 25% ground peanuts • 15% soybean or rapeseed/canola oil • 28% sugar (lactoserum, maltodextrin) • 2% vitamins and minerals, including macrominerals (type II nutrients)	**…to, options** • Lower the milk content • Replace milk powder with whey concentrate • Use soy protein isolates (provided that phytate content is lower) • Use other legumes, such as beans, peas, or lentils, instead of peanuts • When replacing peanuts, their oil content needs to be compensated for	**Comments/drawbacks** • Minimum milk content is unknown • Whey availability is linked to cheese production • If milk contains growth factor, soy protein is disadvantageous • Protein content of lentils and beans is comparable to that of soybeans and peanuts (20–30 g/100 g vs. 35 and 23g/100 g, respectively), but they contain very little fat (< 1 g/100 g vs. 18 and 45 g/100g, respectively) and have relatively high amounts of phytate and other antinutrients. Thus with how to reduce antinutrients, enzymes? • Texture, consistency, and homogeneity to be adapted

FIG. 2. Steps to be explored for the development of an effective ready-to-use supplementary food of lower cost than ready-to-use therapeutic food (RUTF) for moderately malnourished children

However, fortified blended foods are not well adapted to meet the nutritional needs of young or moderately malnourished children, for several reasons [24–27]:

» They do not contain all the required nutrients in adequate amounts;
» They contain a relatively large amount of antinutrients and fibers, especially when prepared from nondehulled soybeans and nondegermed, nondehulled maize or wheat (see below);
» They do not provide enough energy per serving and are bulky;
» The overall fat content and essential fatty acid levels are low;
» They contain no milk powder, which increasingly appears to be important for linear growth of young malnourished children [7, 8].

The issue of too low energy density has been partly addressed in supplementary feeding programs by providing the corn–soy blend (or wheat–soy blend) together with oil and sugar (commonly reported weight-based ratio, 10:1:1; see program section, **'Current programs for moderately malnourished children',** below for more information on ratios used). Sometimes these ingredients are mixed together in the feeding or health center before distribution; other times they are provided alongside corn–soy blend to be mixed at home. Unfortunately, very little is known about the preparation and consumption of corn–soy blend at home, both by the malnourished child and by his or her family members.

Figure 3 summarizes the advantages and disadvantages of corn–soy blend and other fortified blended foods when provided to young moderately malnourished children, as well as options that are or may be considered for improvement. The options for improving the nutritional quality range from modifications that are relatively easy to implement (changing micronutrient premix, adding milk powder, dehulling soybeans) to those that require substantial adjustments to the production process (degerming maize, adding more oil during production, exploring use of phytase during production).

To limit the costs of improving corn–soy blend, some of the improvements could be applied to fortified blended foods used for young malnourished children but not necessarily to fortified blended foods used for other vulnerable groups (pregnant and lactating women, people suffering from HIV/AIDS or tuberculosis). For practical reasons, however, the number of different varieties of fortified blended food used in an operation should be limited (preferably to not more than two) in order not to confuse program implementers and beneficiaries with different, but very similar, products for different target groups that all have to be distributed and prepared separately.

The three main buyers and distributors of corn–soy blend are the World Food Programme (WFP), UNICEF, and the US Agency for International Development (USAID). The characteristics of the products they purchase are described below.

TABLE 3. Classification of complementary food supplements

Kind of product (examples)	Nutrients and active substances contained	Ingredients used	Impact shown or expected	Most appropriate target groups
MN powders (Sprinkles, MixMe)[a]	MNs (type I and zinc)	MNs and carrier (maltodextrin or rice flour)	Yes, on nutritional anemia Assumed to have impact on other MN deficiencies as well	Those with MN deficiencies; not very effective for promoting linear growth
Powdered complementary food supplements, consisting of protein and/or specific amino acids and MNs (Ying yang Bao, TopNutri)	MNs, some with macrominerals (i.e., type II nutrients), high-quality protein, or limiting amino acids	MNs, soy protein concentrate or processed whole-fat soybean flour (also contains essential fatty acids), additional amino acids (lysine) for some	Formulation using whole-fat soybean flour with 6 mg iron as NaFeEDTA,[b] impact shown on anemia and linear growth Providing several nutrients essential for linear growth Impact depends on bioavailability of vitamins and minerals and should possibly be enhanced with dairy protein and essential fatty acids	Those at risk for faltering linear growth (6–24 mo) Impact on growth remains to be proven
Powdered complementary food supplements, consisting of protein and/or specific amino acids, enzymes, and MNs (MixMe Plus)[c]	MNs, macrominerals for some (i.e., type II nutrients), high-quality protein or limiting amino acids, enzymes for malting or phytate destruction	MNs, macrominerals (calcium, potassium, magnesium?), lysine, malt	Impact not yet shown Fortificants should impact MN deficiencies, type II nutrients, and lysine to impact growth, and reduced viscosity to increase energy intake Note: contains no dairy protein or essential fatty acids	Those at risk for faltering linear growth (6–24 mo) Impact to be confirmed
Lipid-based nutrient supplement ≤ 20 g, ~ 108 kcal (Nutributter)	MNs, macrominerals, dairy protein, essential fatty acids (n-3 PUFAs)	**Nutributter**: Peanut paste, sugar, vegetable fat, skimmed-milk powder, whey powder, MNs, maltodextrin, cocoa, lecithin	Yes, study from Ghana showed impact on MN deficiencies, linear growth, motor development [19, 20]	Those at risk for faltering linear growth (6–24 mo) Appears to be most comprehensive complementary food supplement to make up for gap of essential nutrients in complementary foods, but does not compensate for low energy intake nor counteract impact of antinutrients consumed from other foods.

continued

TABLE 3. Classification of complementary food supplements (*continued*)

Kind of product (examples)	Nutrients and active substances contained	Ingredients used	Impact shown or expected	Most appropriate target groups
Good-quality complementary food to be prepared using boiled water, 30 g powder with < 120 mL water provides ~ 120 kcal	MNs, macrominerals, high-quality protein, carbohydrates, vegetable fat	Typical commercially available porridges, made from skimmed-milk powder or soy protein, vegetable fat, rice/corn/wheat/oats, sugar, MNs	Impact not studied More impact expected on growth as well as MN status from porridges containing milk powder rather than soy protein MN content varies widely	Those at risk for faltering linear growth (6-24 mo) Impact to be confirmed
Lipid-based nutrient supplements ≤ 50 g, i.e., high-quality nutrient and energy supplement, ~ 250 kcal (Plumpy'Doz, Indian RUFC)	MNs, macrominerals, high-quality protein, high-quality oil with good n-6:n-3 fatty acid ratio, energy largely from oil and protein	**Plumpy'Doz:** Peanut paste, vegetable fat, sugar, skimmed-milk powder, whey powder, MNs, maltodextrin **Indian RUFC**: Chickpeas, soybean oil, sugar, rice flour, skimmed-milk powder, MNs, soy lecithin	Impact of **Plumpy'Doz** currently being studied Composition is based on RUTF (Plumpy'Nut), but consumed in small amount added to daily diet Question: Are all nutrient needs met and antinutrient effects of other foods overcome? **Indian RUFC** composition and production processes being finalized, subsequently to be tested	Those at risk for faltering linear growth and morbidity during highly food-insecure periods
Lipid-based nutrient supplements ≤ 100 g, i.e., high-quality nutrient and energy supplement, ~ 500 kcal (Plumpy Nut, Supplementary Plumpy, Indian RUFC[d]) Note: Compressed bars and biscuits (BP100) can also be included in this category	MNs, macrominerals, high-quality protein, high-quality oil with good n-6:n-3 fatty acid ratio, energy largely from oil and protein	**Plumpy'Nut:** Peanut paste, sugar, vegetable fat, skimmed-milk powder, whey powder, maltodextrin, MNs, cocoa, lecithin **Supplementary Plumpy:** Peanut paste, sugar, vegetable fat, whey, soy protein isolates, maltodextrin, cocoa, MNs, lecithin **Indian RUFC**: Chickpeas, soybean oil, sugar, rice flour, skimmed-milk powder, MNs, soy lecithin	Impact of **Plumpy'Nut** (or other RUTFs) on growth and MN status has been shown among children suffering from severe acute malnutrition who progressed through moderate acute malnutrition stage to normalcy Note that these children received no other food than RUTF and breast milk, if applicable, during recovery Impact of **Supplementary Plumpy** currently being studied **Indian RUFC** composition and production processes being finalized, subsequently to be tested	Those suffering from moderate acute malnutrition, i.e., in targeted supplementary feeding programs, or for blanket supplementary feeding of young children in highly food-insecure periods or areas

MN, micronutrient; PUFA, polyunsaturated fatty acid; RUFC, ready-to-use food for children; RUTF, ready-to-use therapeutic food

a. *Moringa oleifera* leaf powder could also be considered a micronutrient supplement, but because its composition, including levels of antinutrients and toxic substances, is not well known, it is not included in this table.

b. Note that the Joint FAO/WHO Expert Committee on Food Additives (JECFA) norms for EDTA intake translate to a maximum of 2.5 mg iron from NaFeEDTA for an 8-kg child.

c. Power Flour consists of barley malt but has not been fortified with micronutrients; therefore it has not been listed here.

d. When Indian RUFC is to provide 500 kcal/day, micronutrient content per 1,000 kcal of product will be lower than when providing 250 kcal/day.

Corn–soy blend from WFP*

WFP is currently revising its specifications for corn–soy blend and other fortified blended foods to arrive at mainly two products,** as follows (for more details, see de Pee et al. [28]):

» *Improved corn–soy blend* for general use, including for pregnant and lactating women and people suffering from HIV/AIDS or tuberculosis, which will:
  - Have improved micronutrient content (more kinds, increased amounts, better bioavailability);
  - Use dehulled soybeans in order to make a start with reducing fiber and phytate content and to reduce the content of toxins and contaminants;
  - Have a lower maximum for aflatoxins (5 instead of 20 ppb) and tighter specifications for microbiological content;
  - Include specifications for maximum content of heavy metals;

» *Improved corn–soy blend plus milk* for young (6 to 23 months) and moderately malnourished children, which will have the same specifications as improved corn–soy blend (see above) and in addition contain:
  - Skimmed-milk powder at 8%;
  - Sugar: up to 10% of energy;
  - Oil (soybean): approximately 3% added before extrusion and up to 7% added after extrusion (exact amount to be determined based on product rancidity and shelf-life tests).

The specifications for improved corn–soy blend have been finalized and will be gradually implemented in consultation with producers. For corn–soy blend plus milk, production trials are ongoing to determine the optimal specifications from a technological and shelf-life point of view. Once finalized, this product should be studied in comparison with other products (RUTF, improved corn–soy blend) for its impact on growth (linear growth as well as weight), micronutrient status, functional outcomes, acceptance, and length of stay in blanket or targeted supplementary feeding programs among young (6 to 23 months) as well as moderately malnourished children.

Corn–soy blend from UNICEF (UNIMIX)

UNIMIX, the corn–soy blend procured and distributed by UNICEF, has virtually the same composition as (not yet improved) corn–soy blend procured by WFP, except that it also includes 5% to 10% sugar in exchange for corn. WFP and UNICEF are discussing the improvements that will be made to corn–soy blend and also to UNIMIX.

Corn–soy blend from USAID

The corn–soy blend procured and distributed by USAID complies with the USDA (US Department of Agriculture) Commodity Requirement CSB13 [29] and contains 69.5% cornmeal (“processed, gelatinized”), 21.8% soybean flour (“defatted, toasted”), 5.5% soybean oil (“refined, deodorized, stabilized”), 3% micronutrients, and antioxidant premix. The declared micronutrient content of corn–soy blend from USAID*** is based on the micronutrient content of the raw materials and the micronutrient premix, not on analysis. And, as with the corn–soy blend purchased by WFP, the micronutrient specifications for the premix are currently under review as well (Liz Turner, SUSTAIN, personal communication).

According to the CSB13 requirements, corn shall be dehulled and degermed and corn germ may be added back to the product (maximum 10%) to replace vegetable oil. Soybeans can be added as defatted or full-fat soybean flour. Defatted soybean flour shall be prepared from dehulled soybeans, whereas dehulling is optional for full-fat soybean flour. When full-fat soybean flour is used, it should be added in an amount that ensures that protein content is equivalent to use of 21.8% defatted soybean flour. Vegetable oil may be added to the final product to ensure adequate fat content.

Thus, the corn–soy blend donated by USAID contains less crude fiber, which is also in accordance with the specifications (2% dry matter for USDA specifications and 5%, to be changed to 3%, for WFP), because it uses dehulled (and possibly degermed) corn, and possibly dehulled soybeans (depending on whether defatted or full-fat soybeans are used). For this product, some processing steps identified in **figure 3** are thus being taken already.

A comprehensive overview of the history of US Government Food Aid Programs has been written by Marchione [30]. It is noteworthy that between the mid-1960s and the late 1980s, blended foods contained nonfat dry milk (corn–soy milk and wheat–soy milk) but that milk was dropped from the blends when milk surpluses became exhausted. In 2001, nonfat dry milk was reintroduced in a number of commodities. Requirements for adherence to manufacturing standards, including micronutrient specifications, for US commercial food suppliers to the food aid programs, and their enforcement, were introduced in 1999 and

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* WFP also distributes corn–soy blend donated by USAID and formulated according to USDA specifications, see section below, **‘Corn-soy blend from USAID’.** Here, we describe the specifications of corn–soy blend as purchased by WFP, to a large extent from producers in developing countries.

** In North Korea, WFP purchases blended foods that also include milk powder (milk powder, corn, and soy; milk powder and rice; milk powder and wheat). However, no conclusive evaluation of impact is available on these operations.

*** Available at: http://www.usaid.gov/our_work/humanitarian_assistance/ffp/cr g/downloads/fscornsoyblend.pdf.

TABLE 4. Composition and price, per daily recommended dose, of various complementary food supplements that are already being used or are in final stage of development (see **table 3** for classification and ingredients)

Ingredient	MN powders, nutritional anemia (1 g)	MN powders, 15 vitamins and minerals (1 g)	Soy Sprinkles (10 g)	MixMe Plus (5 g)	TopNutri (7.5 g)	Nutributter (20 g)	Plumpy' Doz, (46 g)	RUFC India[a] (50 g)	Supplementary Plumpy (92 g)	Plumpy' Nut (92 g)
Energy (kcal)			44		20	108	247	260	500	500
Protein (g)			3.8		3.8	2.56	5.9	5	12.5	12.5
Fat (g)			3		< 0.1	7.08	16	15.5	32.9	32.9
Lysine (mg)				400	36% excess					
Malt flour (mg)				1,000						
PDCAAS (%)					100					
Vitamin A (µg)	300	400		400	340	400	400	100	840	840
β-Carotene (µg)								400		
Vitamin E (mg)		5		5	5.6	—	6	3	18.4	18.4
Vitamin B_1 (mg)		0.5		0.5	0.5	0.3	0.5	0.25	0.55	0.55
Vitamin B_2 (mg)		0.5	0.2	0.5	0.7	0.4	0.5	0.25	1.66	1.66
Niacin (mg)		6		6	6.8	4	6	3.7	4.88	4.88
Pantothenic acid (mg)				2	3	1.8	2	0.5	2.85	2.85
Folic acid (µg)	160	150		90	90	80	160	75	193	193
Vitamin C (mg)	30	30		60	45	30	30	30	49	49
Vitamin B_6 (mg)		0.5		0.5	0.6	0.3	0.5	0.25	0.55	0.55
Vitamin B_{12} (µg)		0.9		0.9	0.9	0.5	0.9	1	1.7	1.7
Calcium (mg)			385	400	320	100	387	200	276	276
Magnesium (mg)					90	16	60	40	84.6	84.6
Selenium (µg)		17		17	20	10	17	10	27.6	27.6
Zinc (mg)	5	4.1	4.1	2.5	3.8	4	9	4.1	12.9	12.9
Iron (mg)	12.5	10	6	2.5	7.7	9	9	10	10.6	10.6
Iodine (µg)		90		30	86	90	90	—	92	92
Copper (mg)		0.56		0.34	0.34	0.2	0.3	0.3	1.6	1.6
Phosphorus (mg)					230	82.13	275	75	276	276
Potassium (mg)				400	280	152	310	305	511	1022
Manganese (mg)					0.9	0.08	0.17	0.8	—	—
Vitamin D (µg)		5	280 IU	5	4.9	—		2.5	15	15
Vitamin K (µg)					37.5	—		15	19.3	19.3
Biotin (µg)					18.8	—			60	60

Sodium (mg)					70					
Molybdenum (μg)					7.5					
Chromium (μg)					7.5					
Phytomenadion (μg)				30						
Product cost per dose (US$)	0.02	0.027[b]	?	0.04?	?	0.11	0.2	0.13 (0.26 for 100 g)	0.33	0.41
Minimum no. of doses for 6- to 23-mo-old	225 (150/yr)	225 (150/yr)		225 (150/yr)	225 (150/yr)	180 (daily 6–12 mo)	120?	120?	120?	120?
Total product cost (US$) for required no. of doses	4.5	6.1		9		19.8	24	15.6	39.6	49.2
Supplement to or replacement of normal diet	Supplement	Supplement	Supplement	Supplement	Supplement	Supplement	Supplement or replacement	Supplement or replacement	Replacement	Replacement

MN, micronutrient; PDCAAS, protein digestibility-corrected amino acid score

a. The micronutrient premix that is added to Indian ready-to-use food for children (RUFC) is being modified. The composition shown here was the initial composition and has been used for the calculations in **table 5D–F** and **table 6**.

b. Cost for single-dose packaging. For multidose packaging, cost could go down to US$0.008/dose.

2000. With a total US donation in 2007 of 114,000 metric tons of corn–soy blend, 61,000 metric tons of which was donated through WFP,* good quality control is very important.

Need and feasibility of further adjustments to fortified blended food

As mentioned above, one of the main issues with corn–soy blend that make it less suitable for young malnourished children is the high content of antinutrients, particularly phytate, and its fiber content. A study from 1979 documented that nitrogen absorption and retention (indicating protein uptake) were better from corn–soy blend made from degermed corn and dehulled soybeans than they were from corn–soy blend made from whole cornmeal and dehulled soybean flour or from whole cornmeal and whole soybean flour [23]. These effects were ascribed to the higher fiber content. High fiber content may also reduce energy intake through an effect on appetite, increased fecal losses of energy due to reduced absorption of fat and carbohydrate, and increased flatulence, which can have a further negative effect on energy intake [2] and can also lead to nonacceptance of the product. Although reduced energy uptake could be compensated for by adding oil or sugar to the product, it does not improve mineral bioavailability and also reduces micronutrient density unless fortification levels are increased.

An article by Jansen published in 1980 that reviewed more results, however, concluded that degerming corn also results in loss of protein and oil from the germ and that the higher protein content of whole corn compensates for the slightly lower protein absorption related to its higher fiber content [25]. With regard to the likely lower bioavailability of minerals, Jansen said that this should be compensated by fortification. Given the considerable losses when degermed corn meal is used (extraction rate of 65% to 75%, and thus a loss of 25% to 35%), the desire to produce the product locally, and the possibility to at least dehull the soybeans, Jansen recommended in 1980 that corn–soy blend be composed of dehulled soybeans and whole maize meal, resulting in a crude fiber content of less than 2%, and be mixed with an adequate micronutrient premix.

The USDA specifications include the use of dehulled and degermed corn and dehulled defatted soybeans or optionally dehulled full-fat soybean flour, and up to 10% of corn germ may be added back to the product. Corn–soy blend purchased locally in developing countries by both WFP and UNICEF, however, is made from

* Details about USDA Food Aid can be retrieved from Programs and Opportunities — Food Aid — Food Aid Reports (available at: http://www.fas.usda.gov/excredits/FoodAid/Reports/reports.html).

Fortified blended foods		Options for improving nutritional quality		
Positive • Can be produced almost anywhere • Soybeans: good protein profile • Fortified with micronutrients	**Negative** • Limited impact on growth and MN status • Fiber in nondehulled maize, wheat, and soybeans • Antinutrients in nondegermed maize as well as in wheat and soybeans • Fortified with too few MNs and limited bioavailability • Energy density too low and viscosity too high for young malnourished children	**Limited complexity** • Add dried skimmed milk to promote growth (10%?) • Soybeans: dehulling • Improve MN profile (more MNs and higher amount)	**More complex and costly** • Use soy protein isolates with low phytate content instead of dehulled soybeans • Use degermed and dehulled maize flour (means discarding 25% of maize and altering production steps) • Add sugar (already done for UNIMIX) and oil (soybean, rapeseed/canola) during processing to increase energy density and essential fatty acid content and compensate for oil lost when soy protein isolates rather than soybeans are used	**Worth exploring — phytase[a]** • Reduce phytate by soaking fortified blended food ingredients together with phytase before extrusion cooking and drying (requires equipment: conditioner and dryer) • Reduce phytate by adding phytase to the processed dry product • Reduce phytate by adding phytase to prepared product (i.e., home fortification)

FIG. 3. Steps to be considered for upgrading fortified blended foods to supplementary foods of better nutritional quality for moderately malnourished children. MN, micronutrient

whole maize as well as whole soybeans.*

A study using wheat–soy blend provided by World Vision in Haiti found a poor impact on anemia levels [31]. If the wheat–soy blend was provided under the Title II programs and complied with USDA specifications, the crude fiber content was 2.5% of dry matter, as it contained partially debranned wheat [32]. This means that also for corn–soy blend that complies with USDA specifications it is not known whether the phytate content is low enough to provide for adequate mineral absorption. For young children, a maximum intake of total dietary fiber of 0.5 g/kg body weight has been recommended by the American Academy of Pediatrics. For a 6-kg child, this would translate into 3 g/day. When this child consumes some vegetables and wheat or corn in addition to one or two cups of corn–soy blend, especially when the blend is made from whole maize and whole soybeans, the intake is very likely higher than that.

Therefore, options to reduce fiber and phytate content need to be further explored for the product purchased by WFP and UNICEF. The costs of degerming corn, due to the need for specific equipment, the loss of 25% to 35% of the corn, and the need to compensate for the loss of some protein and oil, are high. This means that if degerming corn were to be done for the products purchased by WFP and UNICEF, it should probably only be done for corn–soy blend that is used for young (6 to 23 months) and for moderately malnourished children.

* Note that the new specifications of WFP that will soon be rolled out require dehulling of soy (see above), and maximum crude fiber will be reduced from 5% to 3%.

Option 4. Complementary food supplements: Compensating for shortage of specific nutrients

Complementary food supplements can be defined as food-based complements to the diet that can be mixed with or consumed in addition to the diet and the purpose of which is to add nutritional value [33]. Complementary food supplements are comparable to food fortification in the sense that they increase the intake of essential nutrients from food. However, the important differences are that complementary food supplements can be targeted to specific vulnerable groups, as they are added to foods just before consumption (home or point-of-use fortification), and that the dosage is not dependent on the amount of energy consumed in a day, i.e., one dose is added to one meal irrespective of meal size.

Complementary food supplements can be divided into different categories, as shown in **table 3**. The first four categories (micronutrient powders, powdered complementary food supplements [protein, amino acids, micronutrients], complementary food supplements that also have active substances (enzymes), and lipid-based nutrient supplements of 10-20 g) are complementary food supplements that provide essential micronutrients, amino acids, fatty acids, and/or active compounds (enzymes) but contain little additional energy. The next three categories (industrially produced complementary foods, 45 g lipid-based nutrient supplements [250 kcal], and 90 g lipid-based nutrient supplements [500 kcal]) are foods of high nutritional value* that also provide a substantial amount of energy. Because they are meant to be consumed in addition to a daily diet, even when partly replacing it, and are composed in such a way that they are the main source of essential nutrients (i.e., they can be combined with a largely staple based diet little more than just carbohydrate sources), they are included in this table on complementary food supplements.

Because complementary food supplements are added to an existing diet, the added value of a particular complementary food supplement depends on the composition of the diet to which it is added and the needs of the target group or individual consuming it. For example, micronutrient powders were originally developed to address nutritional anemia [34] and were then expanded to include a wider spectrum of micronutrients [35]. However, when choosing (or developing) a complementary food supplement to enrich the diet of young (6 to 23 months) or moderately malnourished children, a commodity with additional nutrients, such as essential amino acids and essential fatty acids and a dairy component, may be more appropriate, assuming that local foods do not provide these in sufficient amounts.

Because the concept of complementary food supplements is relatively new, with micronutrient powders developed in the late 1990s being the first, they differ with regard to important ingredients, relatively few data exist on their impact, and depending on their purpose, only certain outcomes have yet been tested [19–22, 34, 36]. However, the concept is promising, because only the additionally required nutrients are added to an otherwise local diet or basic food ration. This limits costs as well as interference with prevailing dietary habits and sourcing of food-assistance commodities. Programmatic experience is required to evaluate the feasibility of their use, including prevention of sharing, required social marketing messages, package design and consumer information, training needs, etc., because the concept of a small food supplement to be consumed exclusively by a specific age group of young children [35].

Table 4 shows the nutrient content, sample price per daily dose as in early 2009, estimate of the number of doses required between 6 and 23 months of age or to treat moderate malnutrition, and price of this number of doses (for further information on fortified complementary foods and supplements see the article by the Infant and Young Child Nutrition Working Group [37]). Clearly, the more nutrients and the more energy the complementary food supplement contains, the more expensive it becomes. However, it is important to realize that the complementary food supplement provides nutrients that would otherwise have to be supplied by a much more diverse diet.

* It should be noted though that the nutritional value of commercially available complementary foods is very variable. They have been listed here, because some are of high value, such as the products developed by Groupe de Recherche et d'exchange Technologiques (GRET) (see **table 8**).

Some adequacy calculations

In order to determine which kinds of complementary food supplements are most suitable to improve a typical complementary feeding diet so that it is likely to meet the nutrient intakes recommended by Golden [1] for moderately malnourished children, **table 5** was prepared using linear programming [38, 39]. It shows the typical nutrient intake of a 12- to 15-month-old, moderately underweight (7.4 kg) Bangladeshi child who is breastfed and receives three servings of locally prepared complementary food per day, consisting of rice, dhal with potatoes, oil, sugar, and dark-green leafy vegetables (a maximum of three portions per day of each) and with or without fish (a maximum of two portions per day) when receiving various types of complementary food supplements. The portion sizes assumed for the local foods are average sizes, and they have been modeled to provide the energy requirement not yet fulfilled by complementary food supplements, breastmilk (40% of total energy intake), and a standardized portion size of rice of 150 g/day (i.e., 23% of total energy intake). The linear programming goal was to achieve the nutrient intakes proposed by Golden [1] and the same as those used in the article by Ashworth and Ferguson [3]. However, it should be noted that the selection of foods for the analyses done in this article was more restricted than in Ashworth and Ferguson's article (up to 9 vs. 24 local foods). In particular, fruits, milk, chapatti, bread, semolina, pumpkin, chicken, and chicken liver were not included here, as it was assumed they may not be available in the poorest households. This makes this analysis very different from the one presented by Ashworth and Ferguson, where a greater selection of foods and somewhat different portion sizes were used.

From **table 5A** to **5B** (kinds of micronutrient powders and powdered complementary food supplements) and from **table 5C** to **5D** (kinds of lipid-based nutrient supplements), the dietary diversity is reduced by excluding fish. Diets that included lipid-based nutrient supplements had a lower dietary diversity in the best-fit model than diets with micronutrient powders or powdered complementary food supplements (**table 5A** to **5D**). The lower dietary diversity is because the energy contribution from lipid-based nutrient supplements (i.e., 12.7% to 57.5% of total energy intake) partly replaced that of local foods.

For the unsupplemented restricted diet, which includes spinach, dhal, potatoes, fish (two kinds), oil, sugar, rice, and breastmilk, without a complementary food supplement, nutrient content is inadequate for 10 micronutrients. With a micronutrient powder with

5 micronutrients, content is inadequate for 7 micronutrients, and with 16 micronutrients it is inadequate for 3, which are type II nutrients. Of all the different kinds of micronutrient powders and powdered complementary food supplements, TopNutri provides the most complete mix of micronutrients. With decreasing dietary diversity, the gap of micronutrients increases. When lipid-based nutrient supplements are added, nutrient intake becomes more complete as compared with when micronutrient powders are added. However, they are still short in a number of nutrients, especially vitamins E and C, potassium, magnesium, and zinc. This may be due to the fact that some lipid-based nutrient supplements are designed for prevention rather than for treating moderate malnutrition (i.e., recommended intakes are different), and other lipid-based nutrient supplements are designed to completely meet the required nutrient intake (with exact intake to be varied according to energy need) rather than to be consumed in addition to a local diet and breastmilk. For the Indian RUFC, the micronutrient content will be adjusted to be comparable to that of Plumpy'Doz when providing 50 g/day and to Supplementary Plumpy when providing 100 g/day.

The same analysis has also been done for the addition of complementary food supplements to corn–soy blend, of which the energy density was increased by the addition of oil and sugar (**table 6**). For corn–soy blend, the composition as published by USDA was used, which is based on the micronutrient content of the raw ingredients and the micronutrient premix and is a relatively complete kind of corn–soy blend. As the table shows, because complementary food supplements are not designed to be added to corn–soy blend, which is already fortified, the intake of several micronutrients would become rather high. However for some, particularly the type II nutrients, intake would still be too low, for similar reasons as mentioned above for the combination of lipid-based nutrient supplements with the local diet. It will be best either to adapt the mew micronutrient premix formulation of corn–soy blend (as will soon be implemented by WFP) or to add an appropriate complementary food supplement to a largely plant-source-based unfortified diet. When adapting corn–soy blend, considerations discussed above should also be taken into account, i.e., ingredients and processing used, in addition to reaching adequate nutrient content.

The results shown should, however, be interpreted with caution, because they are calculated for a hypothetical child aged 1 year, weighing 7.4 kg, who is breastfed, probably by a mother with suboptimal nutritional status herself, and lives in a food-insecure household in Bangladesh. For many children, the situation will be different because they are of a different age, may or may not be breastfed, may have access to a greater variety of foods, etc. The complementary food supplements are of the same size and composition irrespective of the specific age of the under-five child, whether he or she is breastfed, and what the nutritional status is. Thus, adequacy of diet in combination with complementary food supplements will vary among as well as within populations.

Linear programming calculates possible solutions to reach certain goals, such as, in this case, intake of energy, macronutrients, and micronutrients from a specific set of foods that can be consumed at certain minimum and maximum amounts. However, some important aspects of foods for young or moderately malnourished children discussed in this article cannot yet be included in linear programming because of a lack of adequate data or because exact requirements have not yet been established. These include selenium, iodine, biotin, and vitamins K and D (too variable or unknown content); essential fatty acids; PDCAAS, i.e., protein quality; minimum requirement for animal-source food or milk; antinutrients (content in individual foods not well known and maximum intake not established); and micronutrient bioavailability (depends on factors in a meal, not a daily diet, and is very complex).

Further, the linear programming results are very dependent on the model parameters, which for this particular analysis include the list of foods, their portion sizes, and the desired nutrient intake levels. Thus, for households with access to a greater variety of foods or with different food portion size restrictions, the results would differ, as was shown when results from these analyses are compared with those for a breastfed child in Ashworth and Ferguson [3]. Likewise, these results depend on the validity of the nutrient goals modeled. In particular, estimating iron adequacy is complex because it depends on bioavailability, which needs to be judged separately. An additional judgment is also required with regard to protein and fat quality and inclusion of milk powder or another animal-source food (in addition to breastmilk).

Future option: Use of phytase

Another possible option to increase mineral bioavailability is the use of phytase to reduce phytate content, by adding it during production, adding it to an end product as the last production step, or using it as a home fortificant (**fig. 3**). The latter two options, however, cannot yet be used at large scale because phytase is not yet widely approved for human consumption. It has GRAS (Generally Regarded As Safe) status for persons aged 3 years and older, but not yet for younger persons, and in some countries it is not permitted at all. When phytase is used during industrial processing and destroyed by a subsequent heating step, there is no problem because the product that reaches the consumer will not contain phytase.

A range of phytases is available with different pH and temperature optimums; thus different phytases can be used for phytate degradation in different wet foods or in the low-pH environment of the stomach [40]. To what extent phytase reduces phytate, whether used during food production, in prepared, wet, food that is left to stand for a while, or in the stomach, needs to be determined, as should the impact on mineral absorption. Promising results have been obtained from a very recent stable-isotope trial among Swiss women that assessed iron absorption from a maize porridge with high phytate content to which a micronutrient powder with low iron content of high bioavailability and a phytase that degrades phytate both on the plate and in the stomach had been added [41].

Thus, it is of urgent importance to obtain GRAS status for the use of phytase in foods consumed by

TABLE 5A. Comparing nutrient intake requirements as proposed by Golden [1] with the nutrient contents of a daily diet of a 13- to 15-month-old, breastfed, moderately malnourished Bangladeshi child (7.4 kg, 851 kcal/day) to which fixed amounts of different complementary food supplements are added (see also Ashworth and Ferguson [3]). This table: Micronutrient powder or powdered complementary food supplements with fixed amounts of breastmilk and rice, and choice of fish, spinach, dhal, potato, onion, oil, or sugar, all with maximum intake.

Component	Diet without CFS	Diet + MN powder (5 MNs)	Diet + MN powder (16 MNs)	Diet + soy powder with MNs	Diet + MixMe Plus	Diet + TopNutri
Nutrients	% of proposed intake					
Protein	136	171	173	179	175	199
Vitamin A	***73***[a]	111	123	***74***	122	115
Vitamin E	***29***	***47***	***98***	***53***	***89***	100
Vitamin C	***53***	101	100	***43***	137	112
Thiamine	***77***	***87***	185	***93***	180	175
Riboflavin	***62***	***63***	137	***90***	140	168
Niacin	140	177	260	153	248	266
Vitamin B_6	***87***	***83***	156	***60***	144	153
Folic acid	139	159	157	100	187	149
Vitamin B_{12}	278	530	636	408	564	658
Pantothenic acid	117	127	127	122	208	249
Calcium	100	100	100	124	191	182
Phosphorus	103	122	123	104	129	176
Magnesium	***81***	***78***	***78***	***68***	***82***	131
Potassium	***98***	104	103	***91***	129	115
Iron (10% bioavailability)	***67***	203	172	125	100	152
Zinc (moderate bioavailability)	***32***	***73***	***66***	***61***	***57***	***66***
Copper	111	***88***	184	***68***	154	139
Manganese	483	452	453	425	483	556
Diet ingredients	Amount in diet (g)					
Breastmilk, 530 g	530	530	530	530	530	530
Rice, plain, boiled—minimum 150 g	150	150	150	150	150	150
Potato, cooked	56	62	58	0	0	0
Spinach, cooked—maximum 40 g	40	40	40	40	40	40
Onion	0	0	0	0	0	0
Lentil-dhal	80	8	12	39	80	40
Small fish with bones	15	16	16	0	19	21
Fish	0	91	91	127	46	70
Soybean oil	12	12	12	12	12	12
Gur-cane sugar	0	0	0	0	0	0
Supplement (g)		1	1	1	5	8

MN, micronutrient

a. Nutrients for which less than 100% of recommended intake is achieved are displayed in bold italics.

young children (6 to 35 months) and to test its impact on phytate degradation and mineral bioavailability in this target group as well.

Ready-to-use foods vs. to-be-prepared foods: Storage and preparation

So far, we have considered the nutrient content, antinutritional factors, and specific ingredients of specially formulated foods for young, moderately malnourished children. Another important aspect to be considered is the form of these specially formulated foods that are provided as part of supplementary feeding programs, i.e., whether they are ready to use or need to be prepared, how easy and hygienic is their preparation, and how well they can be stored.

These aspects are important for any of the above-discussed options, whether referring to recommendations for foods prepared at home (i.e., germination, storing of fresh fish or meat) or to foods provided as food assistance (transport over considerable distance, storage, cooking fuel availability).

Foods that are ready to use are extremely convenient from the point of view of storage as well as preparation (which is not required) and consumption. Because they are very energy dense and contain very little water (to prevent growth of molds and bacteria), it is important

TABLE 5B. Micronutrient powder or powdered complementary food supplements with fixed amounts of breastmilk and rice, choice of spinach, dhal, potato, onion, oil, or sugar, all with maximum intake (i.e. no fish)

Component	Diet without CFS	Diet + MN powder (5 MNs)	Diet + MN powder (16 MNs)	Diet + soy powder with MNs	Diet + MixMe Plus	Diet + TopNutri
Nutrients	% of proposed intake					
Protein	***97***[a]	***97***	***97***	109	***97***	107
Vitamin A	***73***	109	122	***73***	122	114
Vitamin E	***28***	***28***	***79***	***28***	***79***	***91***
Vitamin C	***56***	103	103	***56***	150	118
Thiamine	***78***	***78***	176	***75***	176	166
Riboflavin	***57***	***57***	131	***85***	131	158
Niacin	106	106	189	100	189	186
Vitamin B_6	***87***	***87***	160	***83***	160	154
Folic acid	139	225	219	133	187	184
Vitamin B_{12}	***60***	***60***	166	***60***	166	166
Pantothenic acid	114	114	114	108	201	230
Calcium	***50***	***50***	***50***	125	129	111
Phosphorus	***67***	***67***	***67***	***63***	***67***	106
Magnesium	***72***	***72***	***72***	***69***	***72***	117
Potassium	***91***	***91***	***91***	***89***	125	100
Iron (10% bioavailability)	***64***	227	194	139	***96***	161
Zinc (moderate bioavailability)	***27***	***72***	***64***	***62***	***49***	***59***
Copper	108	108	204	103	166	149
Manganese	466	466	466	452	466	535
Diet ingredients	Amount in diet (g)					
Breastmilk, 530 g	530	530	530	530	530	530
Rice, plain, boiled – minimum 150 g	178	178	178	150	178	150
Potato, cooked	62	62	62	62	62	28
Spinach, cooked – maximum 40 g	40	40	40	40	40	40
Onion	20	20	20	20	20	0
Lentil-dhal	80	80	80	74	80	80
Soybean oil	12	12	12	12	12	19
Gur-cane sugar	0	0	0	0	0	0
Supplement (g)		1	1	1	5	8

MN, micronutrient

a. Nutrients for which less than 100% of recommended intake is achieved are displayed in bold italics.

that those who consume them have access to clean drinking water. Where the availability of cooking fuel or time for food preparation is limited, providing a RUF for an individual suffering from a special condition, such as a malnourished child, will be easier than providing a food that needs to be prepared separately from the family meal. In addition, a food that needs to be cooked specifically for one individual may be more likely to be shared with other family members.

The same advantage applies to biscuits or compressed bars, which are also ready to use. There is concern about using biscuits for complementary feeding because of the difficulty for consumers of distinguishing between nutritious and non-nutritious biscuits and the possible promotion of a habit of biscuit consumption, which may in fact lead to consumption of non-nutritious, high-sugar biscuits. However, when biscuits are used for feeding children with severe acute malnutrition (BP100), used as a short-term measure for reducing the risk of malnutrition under sudden situations of food insecurity (BP5), or used to feed children with moderate malnutrition for a limited period of time, these concerns do not apply. When designing biscuits as RUF, it is important to realize that baking

TABLE 5C. Lipid-based nutrient supplements with fixed amounts of breastmilk and rice, choice of fish, spinach, dhal, small fish with bones, potato, onion, oil, or sugar, all with maximum intake

Component	Diet + Nutributter (20 g)	Diet + Plumpy'Doz (45 g)	Diet + Indian RUFC (50 g)	Diet + Supplementary Plumpy (90 g)	Diet + Plumpy'Nut (90 g)
Nutrients	% of proposed intake				
Protein	135	127	111	***89***	***89***
Vitamin A	122	122	85	138	138
Vitamin E	***39***[a]	***91***	***54***	197	197
Vitamin C	***89***	***88***	***87***	109	109
Thiamine	118	157	***97***	129	129
Riboflavin	114	125	***87***	268	268
Niacin	178	183	140	100	100
Vitamin B_6	93	115	***76***	***89***	***89***
Folic acid	104	145	100	129	129
Vitamin B_{12}	421	346	326	256	256
Pantothenic acid	176	179	106	165	165
Calcium	100	122	100	***84***	***84***
Phosphorus	100	115	***71***	***69***	***69***
Magnesium	***69***	***87***	***74***	***63***	***63***
Potassium	***82***	***87***	***81***	***68***	109
Iron (10% bioavailability)	148	145	159	140	140
Zinc (moderate bioavailability)	***58***	***98***	***55***	121	121
Copper	***92***	100	102	296	296
Manganese	435	422	493	321	321
Diet ingredients	Amount in diet (g)				
Breastmilk, 530 g	530	530	530	530	530
Rice, plain, boiled—minimum 150 g	150	150	150	13	13
Potato, cooked	6	0	0	0	0
Spinach, cooked—maximum 40 g	40	40	40	5	5
Onion	0	0	0	0	0
Lentil-dhal	0	0	1	0	0
Small fish with bones	10	0	5	0	0
Fish	57	66	31	0	0
Soybean oil	12	0	0	0	0
Gur-cane sugar	0	0	0	0	0
Supplement	20	46	50	90	90

RUFC, ready-to-use food for children

a. Nutrients for which less than 100% of recommended intake is achieved are displayed in bold italics.

TABLE 5D. Lipid-based nutrient supplements with fixed amounts of breastmilk and rice, choice of spinach, dhal, potato, onion, oil, or sugar, all with maximum intake (i.e. no fish)

Component	Diet + Nutributter (20 g)	Diet + Plumpy'Doz (45 g)	Diet + Indian RUFC (50 g)	Diet + Supplementary Plumpy (90 g)	Diet + Plumpy'Nut (90 g)
Nutrients	% of proposed intake				
Protein	***97***[a]	100	***91***	***89***	***89***
Vitamin A	122	122	***85***	138	138
Vitamin E	***28***	***79***	***48***	197	197
Vitamin C	***89***	***88***	***88***	109	109
Thiamine	120	149	***97***	129	129
Riboflavin	112	124	***86***	268	268
Niacin	138	156	121	100	100
Vitamin B_6	***97***	119	***79***	***89***	***89***
Folic acid	173	187	132	129	129
Vitamin B_{12}	119	166	178	256	256
Pantothenic acid	170	171	103	165	165
Calcium	***67***	123	***86***	***84***	***84***
Phosphorus	***73***	100	***57***	***69***	***69***
Magnesium	***68***	***88***	***74***	***63***	***63***
Potassium	***79***	***84***	***80***	***68***	109
Iron (10% availability)	175	162	171	140	140
Zinc (moderate availability)	***59***	101	***55***	121	121
Copper	112	118	113	296	296
Manganese	448	443	500	321	321
Diet ingredients	Amount in diet (g)				
Breastmilk, 530 g	530	530	530	530	530
Rice, plain, boiled – minimum 150 g	150	150	150	13	13
Potato, cooked	6	3	0	0	0
Spinach, cooked – maximum 40 g	40	40	40	5	5
Onion	0	0	0	0	0
Lentil-dhal	0	46	36	0	0
Soybean oil	10	0	0	0	0
Gur-cane sugar	57	0	0	0	0
Supplement	12	46	50	90	90

RUFC, ready-to-use food for children
a. Nutrients for which less than 100% of recommended intake is achieved are displayed in bold italics.

biscuits at up to 200°C will destroy some of the heat-sensitive vitamins. Compressed biscuits, such as BP100 and BP5, do not have this problem.

For precooked dry foods that are to be prepared with water to make a porridge, boiling for 5 to 10 minutes is recommended in order to kill any microbes that could be in the water or the food. Instant foods that only require adding warm water are not preferred for use under less hygienic circumstances.

Current programs for moderately malnourished children

Tables 7 and **8** summarize the responses received to a questionnaire on current programs for moderately malnourished children that was sent to 10 UN agencies and donors, 20 international NGOs, 3 prominent pediatric associations, and 6 large national programs. The information included in this article pertains to the responses that included provision of a food supplement. For a more detailed description of the questionnaire, responses received, and information about programs providing dietary advice, see the article by Ashworth and Ferguson [3].

TABLE 6. Nutrient requirements proposed by Golden [1] compared with nutrients provided by corn–soy blend (USDA composition, see ref 29) with oil and sugar (3 times per day 35 g CSB + 3.5 g oil + 3.5 g sugar) combined with different complementary food supplements, consumed by 13- to 15-mo-old, breastfed, moderately malnourished child (7.4 kg, 851 kcal/day)

Component	CSB without CFS	CSB + MN powder (5 MNs)	CSB + MN powder (16 MNs)	CSB + soy powder with MNs	CSB + MixMe Plus	CSB + TopNutri	CSB + Nutributter (20 g)	CSB + Plumpy'Doz (45 g)	CSB + Indian RUFC (50 g)	CSB + Supplementary Plumpy (90 g)	CSB + Plumpy'Nut (90 g)
Nutrients	% of proposed intake										
Protein	112	112	112	123	112	127	106	100	***93***[a]	***90***	***90***
Vitamin A	140	176	189	130	189	177	166	136	***97***	137	137
Vitamin E	110	110	161	102	161	164	***90***	124	***91***	200	200
Vitamin C	***96***	143	143	***91***	190	164	130	112	111	110	110
Thiamine	126	126	***224***	117	***224***	***220***	163	172	122	131	131
Riboflavin	***98***	***98***	172	121	172	198	142	136	99	***268***	***268***
Niacin	170	170	***253***	158	***253***	***258***	195	185	150	102	102
Vitamin B_6	***81***	***81***	155	***75***	155	166	109	118	***80***	***89***	***89***
Folic acid	185	***271***	***266***	171	***233***	***227***	194	192	143	130	130
Vitamin B_{12}	179	179	***284***	168	***284***	***280***	***212***	***225***	235	260	260
Pantothenic acid	190	190	190	178	***278***	***315***	***237***	***204***	136	168	168
Calcium	195	195	195	***256***	***273***	***251***	179	190	149	***88***	***88***
Phosphorus	56	56	56	52	56	99	63	88	49	69	69
Magnesium	13	13	13	13	13	66	22	46	35	60	60
Potassium	24	24	24	24	58	48	37	49	***50***	***65***	107
Iron (10% bioavailability)	***233***	***396***	***363***	***291***	***266***	***324***	301	***238***	***245***	145	145
Zinc (moderate bioavailability)	51	96	88	84	***74***	***84***	***78***	109	***65***	121	121
Copper	179	179	***276***	166	***238***	***232***	181	156	151	***299***	***299***
Manganese	382	382	382	376	382	468	375	365	424	314	314
Diet ingredients	Amount in diet (g)										
Breastmilk	530	530	530	530	530	530	530	530	530	530	530
Soybean oil	10	10	10	9	10	10	8	5	5	0	0
Gur-cane sugar	10	10	10	9	10	10	8	5	5	0	0
Corn–soy blend	101	101	101	92	101	97	79	53	49	3	3
Supplement		1	1	5	5	8	20	45	50	90	90

CFS, complementary food supplement; MN, micronutrient; CSB, corn-soy blend.

a. Nutrients for which less than 100% or more than 200% of recommended intake is achieved are displayed in bold italics.

TABLE 7. Fortified blended food mixtures provided by organizations implementing supplementary feeding programs for children with moderate acute malnutrition

Organizations implementing and location[a]	No. of children/yr[b]	Corn–soy blend (g/day)	Oil (g/day)	Sugar (g/day)	Additional information
Action Contre la Faim (USA) East and Central Africa Tajikistan	42,000	180-200	20	20	Mixed before distribution. Target: 1,000 kcal/day. Also providing vitamin A capsules, iron/folic acid, mebendazole
Concern West Darfur Democratic Republic of the Congo)	16,500	200	20	20	In case of pipeline break of WFP, maize/soybean mixture purchased locally, but unfortified
Concern South Sudan	5,000	200	30	30	
Concern Niger	?	250	25	15	
Food for the Hungry Bolivia Democratic Republic of the Congo Kenya	57,000	400	31		
GOAL Ethiopia	?	277	33 mL		
GOAL Malawi	?	357			
Helen Keller International	40,000				
Niger		250	25	15	
Burkina Faso		200	20	15	
Mali		250	25	20	
Save the Children (UK) 6 African countries Afghanistan	30,000	Different ratios			

continued

The majority of programs provide fortified blended food, especially corn–soy blend, to moderately malnourished children, who are mostly wasted. **Table 7** shows the number of children reached with a mixture of corn–soy blend + oil + sugar by reporting programs. The total amounts to more than 550,000. Considering that many more programs are implemented, it can be estimated that at least 2 million moderately wasted children receive corn–soy blend (or wheat–soy blend) every year.

The majority of programs add oil and sugar to the fortified blended food, usually by mixing it with the food just before distribution (including oil reduces shelf-life), but sometimes by handing out the three commodities separately.* The ratio of corn–soy blend:oil:sugar varies, as was also observed in the Save the Children (UK) review of supplementary feeding programs by Navarro-Colorado [27]. On average, the ratio is 10:1:1, and approximately 1,000 kcal/day is provided.

* UNIMIX (corn–soy blend provided by UNICEF) already contains sugar, usually 10% in exchange for corn.

Most organizations that answered the question on target intake from the corn–soy blend mixture for the malnourished child stated that this was 1,000 kcal/day (equivalent to 200 g of corn–soy blend + 20 g of oil + 20 g of sugar), while at the same time they said that they provided the corn–soy blend mixture as a take-home ration that was likely to be shared. Considering that the energy needs of a moderately malnourished 6.7-kg child 12 to 15 months of age with a weight gain target of 5 g/kg/day are 770 kcal/day and that many children also receive breastmilk, a target intake of 1,000 kcal/day from corn–soy blend is excessively high for many moderately wasted children and is also not possible to attain for a child who consumes three or four meals per day of 35 g dry weight each. However, unfortunately, little is known about actual intakes of corn–soy blend preparations by different age groups of moderately wasted children. Some programs provided family food rations or a supply of corn–soy blend for siblings to limit sharing of the corn–soy blend mixture that was provided to the moderately wasted child.

A number of organizations provided other kinds

TABLE 7. Fortified blended food mixtures provided by organizations implementing supplementary feeding programs for children with moderate acute malnutrition *(continued)*

Organizations implementing and location[a]	No. of children/ yr[b]	Corn–soy blend (g/day)	Oil (g/day)	Sugar (g/day)	Additional information
GTZ–UNHCR Kenya	7,955	250	25	20	
International Rescue Committee—UNHCR Kenya	?	270 (UNIMIX)	25		UNIMIX already contains sugar. Target: 1,000–1,200 kcal/day
Médecins sans Frontières (Spain) Uganda	3,532	300	40	20	Reflects program June 2007–April 2008 Planned to change to RUFs in May 2008
UNHCR Djibouti	1,000	250	40	20	
UNHCR Uganda	2,000	229	29	29	
UNHCR Tanzania	2,671	120	20	20	Target: 1,000 kcal/day
UNICEF Niger	350,000	250	25	15	Families or siblings receive another ration, to maximize intake of the supplementary feeding ration by the target child. Target: 1,200 kcal/day Replaces other foods in the diet
Valid Ethiopia Sudan Zambia Malawi		Different ratios, depending on organization supported			

GTZ, Gesellschaft für Technische Zusammenarbeit; RUF, ready-to-use food; UNHCR, United Nations High Commissioner for Refugees

a. It should be noted that most of the corn–soy blend (or wheat–soy blend) distributed by the organizations listed below is donated either by the World Food Programme, which has received it from the United States or purchased it from local producers in a range of countries, or by UNICEF.

b. Most organizations provided the number of beneficiaries for supplementary feeding programs in 2007.

of food supplements (**table 8**). Some (reaching about 200,000 children) provided a mixture of fortified staple, pulse, oil, and sugar (UNICEF Uganda, Church World Service Indonesia, Bangladesh National Nutrition Program, and Action Contre la Faim Myanmar), some of which was locally produced, or BP5 (UNICEF Uganda). Some provided a supplement that also included milk and still had to be cooked, such as the fortified blended food mixtures (DREAM for HIV-positive children in African countries and GRET in Burkina Faso, Madagascar, and Vietnam). World Vision in Niger promoted home preparation of a local peanut paste mixed with dried moringa leaf concentrate for mildly malnourished children and provided the corn–soy blend mixture to moderately malnourished children (see **table 8** for details). A few organizations use lipid-based RUFs such as Supplementary Plumpy, Indian RUFC, peanut/soybean paste, Plumpy'Doz, or Plumpy'Nut for children with moderate acute malnutrition (Médecins sans Frontières, Action Contre la Faim WFP, Project Peanut Butter in Malawi) or even to prevent malnutrition [42]. A rough estimate of the number of children with moderate acute malnutrition receiving a lipid-based RUF is a maximum of 50,000 per year. Note that most lipid-based RUF is in the form of RUTF and is provided to children suffering from severe acute malnutrition.

Further programmatic considerations

Much of the discussions of this Consultation focused on the nutrient and food needs of individual malnourished children, which are a function of the percentage of lean body mass that they should gain and the desired weight gain, which are in turn dependent on the individual's nutritional status (stunted, wasted, or both) as well as on whether a specific food will be provided or whether the diet should be changed. However, from a programmatic point of view, it will rarely be feasible to really tailor the treatment to the individual moderately malnourished child.

In targeted programs that identify the individual malnourished (usually wasted) child, weight and height measures will be taken, a target for weight gain will be set, and the caretaker will be provided with dietary advice and complementary food supplements or special foods. The programs have no control over the diet consumed. Also, giving specific advice and different amounts of commodities to individual children depending on their needs is challenging, especially when working with community volunteers rather than medically or nutritionally qualified personnel or when workload is high. Furthermore, the number of different commodities and their quantities should be limited to reduce errors.

With the current development of new concepts and products for different types of malnutrition, many questions arise about what programs to implement or how to modify ongoing programs, and what advice or commodities to use. Although these program-related questions will be the subject of a follow-on meeting to be organized by WHO and partner organizations towards the end of 2009, some of them need to be answered now, even though it is clear that guidance is likely to change as more products and information about their use and impact become available. **Table 9** suggests response options that can be considered for food-assistance programs to prevent and treat moderate and mild child malnutrition (wasting, stunting). Which choice to make will depend on many factors, including:

» What is likely to have the best impact;
» Logistical considerations, such as the accessibility of the area and presence and capacity of implementing partners;
» Availability of preferred commodities within the desired time frame;
» Human capacity for designing, supervising, implementing, and evaluating the program;
» Funding for the program.

In situations of severe food insecurity where blanket supplementary feeding programs are implemented for young children and pregnant and lactating women, often also for reasons of logistics and safety, foods could be provided of which the composition is as recommended for treating moderate malnutrition, because these are designed to be inherently safe for nonmalnourished individuals. Because of the larger number of beneficiaries, blanket feeding of high-quality and more expensive food supplements comes at a higher commodity cost. However, at the same time, money is saved because there is no need to identify and follow individual moderately malnourished children.

Access to, affordability of, and distribution of specially formulated foods

Because treatment of severe acute malnutrition is considered a right of the child and is too costly for most families (about US$50 for one child's treatment with RUTF), it is generally provided by the public sector (governments or humanitarian agencies). For moderate malnutrition, however, the situation depends on the target group, the commodities, and the context.

For preventive purposes, complementary food supplements such as micronutrient powders, powdered complementary food supplements, and lipid-based nutrient supplements of 20 g/day or less, can be taken,with a product cost (subject to change) of US$0.02 to US$0.12/day. Although they should be used by the majority of children who consume too few animal-source foods and fortified complementary foods, they cannot be afforded by all households [43].

Ways are sought to target different socioeconomic groups in a country in different ways with the same product, which may be packaged differently for this purpose, so that wealthier households can cross-subsidize poorer households and public sector organizations can buy and distribute to the poorest. The use of vouchers for specific groups that are targeted for specific public programs is also considered [44].

Preventive or curative approach

Based on the successful treatment of severe acute malnutrition with RUTF, attention now focuses on the treatment of moderate acute malnutrition, the guidelines for which are similar to those for prevention of wasting and growth-faltering among children aged 6 to 23 months. Also, as explained by Golden [1], when treating children with moderate acute malnutrition, weight gain should be due mainly to increase in lean tissue and hence should also result in linear growth (note that many wasted children are also stunted). Among non-wasted children, it is better to prevent stunting between conception and 24 months of age than to treat stunting after it has occurred [45].

Thus, a good strategy for a population would be to focus on preventing malnutrition through programs that target pregnant and lactating women and children aged 0 to 23 months, and on treatment of moderate and severe wasting among children under 5 years of age. The former can also be considered treatment of a population; i.e., based on the prevalence of stunting among 2- to 5-year-olds, the younger children receive blanket treatment to reduce their risk of becoming malnourished. Ruel et al. [46] conducted a trial in which they compared two populations; in one population all children aged 6 to 23 months received a monthly supply of fortified blended food and oil, and in the other population all children aged 6 to 59 months suffering from moderate acute malnutrition received a monthly supply of the same. Three years later, the population levels of malnutrition were lower in the former than in the latter group, and the authors concluded that the former strategy was more effective for combating undernutrition.

What appropriate preventive measures are depends on the adequacy of the local diet, i.e., which dietary gap has to be filled, and on the accessibility of required foods. For treating moderate acute malnutrition, locally available foods can be used where accessible [3]. Where this option is not very feasible, processed and fortified

TABLE 8. Other foods provided to moderately malnourished children

Organizations implementing and location	Food ration provided, ingredients	Target group	Comments
UNICEF Uganda	Corn–soy blend + oil + sugar, or BP5 when these ingredients are not available	50,000–70,000 moderately malnourished children	
Church World Service Indonesia	Wheat–soy blend and recipes, with demonstration, such as cake, meatballs, etc., and fortified food from Kids Against Hunger, made of rice, soybean flour, dried vegetables, salt, maltodextrin, dextrose, hydrolyzed soy protein, soybean oil, and MNs	Children with moderate acute malnutrition on Nias and West Timor Islands	
BNNP Bangladesh	20 g roasted rice, 10 g roasted lentils, 5 g molasses, 3 mL oil (total 150 kcal)	91,435 children/yr, 150 kcal/day for underweight 6- to 11-mo-olds and 300 kcal/day for underweight 12- to 23-mo-olds	
Action Contre la Faim (France) Myanmar	Fortified mixture of 125 g rice, 125 g yellow beans, and 50 g sugar, with 43 g oil added just before distribution. Instant food, requires adding hot water. Locally produced	11,650 children/yr, moderately malnourished < 5 yr	A study was planned for 2nd half of 2008, to compare impact of this mixture with that of Plumpy'Doz and Supplementary Plumpy
World Vision Niger	3 different treatment groups receiving different foods under different schemes: Severe acute malnutrition: RUTF Moderate malnutrition: corn–soy blend (250 g) + oil (25 g) + sugar (15 g), referred to as "therapeutic food" Mild malnutrition: PD/Hearth + locally made food supplement Zogala Nut (leaf powder from *Moringa oleifera* [25%], peanut paste [55%], sugar [10%], peanut oil [10%], and iodized salt)	So far, in 2008: #12,929 < –3 Z scores (W/H < 70%) or MUAC < 110 mm # 1,167 –3 and –2 Z scores (70% < W/H < 80%) #560 –2 and –1 Z Scores (80% < W/H < 85%) and stunted All received MNs (vitamin A, iron/folic acid, zinc, vitamin C) 23,000 healthy children enrolled in growth monitoring	Depending on the amount of Zogala Nut consumed and the composition of the local diet, the foods consumed by the mildly malnourished may be of similar nutritional value as the corn–soy blend/oil/sugar diet The source of nutrient content of Zogala Nut has not been specified and is likely to vary because it is locally prepared (most MNs are from the leaf concentrate, i.e., no fortification) Numbers of mildly and moderately malnourished are very small compared with those with severe acute malnutrition
DREAM 9 African countries: all programs related to HIV/AIDS)	A variety of mixes, e.g., 70 g corn–soy blend/wheat–soy blend, 5 g oil, 8 g sugar, 25 g skimmed-milk powder	3,000 children who are HIV+ or born to HIV+ mothers/yr	

continued

TABLE 8. Other foods provided to moderately malnourished children *(continued)*

Organizations implementing and location	Food ration provided, ingredients	Target group	Comments
GRET in collaboration with IRD, Montpellier Madagascar Vietnam Burkina Faso	Developed complementary foods for feeding young children (6–23 mo) to prevent malnutrition Target population ~ 150,000 children. Recommended consumption 70–140 g/day from the following mixtures: Madagascar: maize, rice, soybeans, peanuts, sugar, salt, MNs, α-amylase Vietnam: rice, soybeans, sugar, milk powder, sesame, salt, MNs (produced by very-low-cost extrusion cooking) Burkina Faso 1: millet, soybeans, sugar, sesame, cowpeas, milk powder, salt, MNs, α-amylase Burkina Faso 2: millet, soybeans, peanuts, sugar, salt, MNs, α-amylase Burkina Faso 3: sorghum, millet, soybeans, sugar, peanuts, monkey bread, salt, MNs, α-amylase Burkina Faso 4: maize, soybeans, sugar, peanuts, milk powder, salt, MNs, α-amylase		GRET supports local enterprises to produce fortified infant food and to sell it to the poor at adapted price Note that 5 of 6 mixtures contain α-amylase (to reduce viscosity), 3 contain milk powder, and staple (maize, rice, millet, or sorghum) is the main ingredient in all. No studies available on impact
Project Peanut Butter Malawi	125 g peanut/soybean paste providing 75 kcal/kg/day and 1 RDA of all MNs. The paste is made from 25% whole roasted soybeans, 20% soybean oil, 26% peanut paste, 27% sugar, and 2% MNs	2,000 moderately malnourished children/yr	This has replaced the use of corn–soy blend, oil, and sugar in these operations
WFP Ethiopia Somalia Myanmar	Supplementary Plumpy, 90 g/day	Targeted distribution to moderately wasted children < 5 yr in Ethiopia and Somalia	
	Improved corn–soy blend with milk powder	Blanket distribution to children < 2 yr in Somalia	
	Indian RUFC + Plumpy'Doz	Blanket distribution to children < 2 yr affected by Myanmar cyclone	
Action Contre la Faim Sudan South Darfur	Supplementary Plumpy, 2 × 90 g/day	5,000 children in 2007, moderately wasted (WH ≥ 70% and < 80% and/or MUAC ≥ 110 and < 120 mm (6–18 mo old), only during hunger gap Jun-Oct 2007	Questionnaire response says that it is complementary to the diet, not a replacement However, it provides 1,000 kcal/day for 6- to 18-mo-old children (!)
Médecins sans Frontières (Suisse) Niger Sudan Somalia	2 sachets Plumpy'Nut/child/day, i.e., 1,000 kcal/day	10,000 moderately malnourished children/yr	This replaced the use of corn–soy blend, oil, and sugar in these MSF Suisse operations
Médecins sans Frontières (France) Niger	Children with moderate and severe acute malnutrition treated with Plumpy'Nut (2006) Blanket distribution of Plumpy'Doz during lean season (2007) as preventive measure	2006: 60,000 cases of moderate acute malnutrition and 5,000 of severe acute malnutrition	The preventive distribution in 2007 reduced case load of moderate acute malnutrition and severe acute malnutrition and limited the burden on health-care system of identifying and following malnourished individuals

BNNP, Bangladesh National Nutrition Program; GRET, Groupe de Recherche et d'exchange Technologiques; IRD, Institut de Recherche pour le Développement; MN, micronutrient; MUAC, mid-upper-arm circumference; PD/Hearth, Positive Deviance/Hearth Program; RDA, recommended dietary allowance; RUFC, ready-to-use food for children; RUTF, ready-to-use therapeutic food; WH, weight-for-height; WFP, World Food Programme foods or complementary food supplements can be made available through subsidies or for-free distribution. Such foods can be produced locally or imported, depending on ingredient availability, local producer capacity, and packaging facilities.

When specially formulated foods are used for treating moderate acute malnutrition, the results should preferably be obtained more quickly than when the diet is modified, because delivery of such products incurs program costs, and there is a greater expectation of the foods' being a treatment (the argument that the food is a treatment for the specific child should also prevent sharing with other household members). When treatment relies on dietary changes, it will hopefully result in a change of the diet of all young children in the family that is maintained for a longer period of time.

Discussion and conclusions

Many of the recommendations for dietary management of moderate malnutrition in children, including the use of specific food supplements, also apply to children aged 6 to 23 months who are at risk for becoming malnourished because they live in populations with a high prevalence of stunting as well as wasting. Therefore, most of what is discussed in this article is applicable to young children (6 to 23 months) as well as to moderately malnourished children (weight-for-height z-score < -2 and ≥ -3 or height-for-age z-score < -2).

Important foods for young and/or malnourished children include breastmilk, staples (for energy and some micronutrients), animal-source foods (good sources of protein, minerals, and some vitamins), legumes or lentils (particularly for protein), vegetables and fruits (for vitamins, minerals, and vitamin C to enhance nonheme iron absorption), oil (for energy and essential fatty acids), and a source of iodine such as salt (but high sodium intake in moderately malnourished children is not desirable). Particularly important components of the diet are protein quality, essential fatty acid content, bioavailability of micronutrients, and limited antinutrient content, as well as high energy and nutrient density.

These requirements are difficult to fulfill when a diet includes few animal-source foods and fortified foods. A largely plant-based diet with few fortified foods is disadvantageous, because of a relatively high content of antinutrients, lower bioavailability of certain micronutrients (iron, vitamin A), and the lack of specific nutrients and active compounds contained in animal-source foods. Breastfeeding is an important source of several nutrients, but also needs to be complemented by animal source foods and fortified foods.

When the diet is largely based on plant sources, three main options can be considered for modification or development of food commodities for young or moderately malnourished children:

- Improving the current standard of fortified blended foods by reducing phytate content by dehulling and/or degerming of corn and soybeans, improving micronutrient premix specifications, and adding milk powder, sugar, and oil;
- Modifying the RUTF recipe to develop RUSF (ready-to-use supplementary food) using local foods as much as possible and limiting costs, for example, by reducing milk content, replacing some dairy protein with soy protein (extracts), using chickpeas or sesame instead of peanuts, and making biscuits or bars instead of a lipid-based food;
- Development of complementary food supplements that add the nutrients, ingredients, and active compounds to diets that are not contained in adequate amounts.

Different categories of complementary food supplements can be distinguished, ranging from micronutrient powder, powdered complementary food supplements of protein, amino acids, and/or enzymes and micronutrients, to lipid-based nutrient supplements that range from 20 to 90 g/day (120 to 500 kcal/day) and typically contain milk powder, essential oil, peanut paste, sugar, and micronutrients. Some complementary food supplements are primarily used for prevention of malnutrition ($\leq$ 20 g/day), whereas others ($\geq$ 40 g/day) are used for blanket or targeted supplementary feeding of malnourished individuals or populations with a high prevalence of malnutrition.

Although we know what nutrients are required, which antinutrient contents should be reduced, and what foods should ideally be used, choosing effective, available, appropriate, and cost-effective foods is a challenge. This is due to a number of factors, including the following:

- The fact that as yet, only a few of the above-mentioned specially formulated foods and food supplements have been assessed in terms of their impact on recovery from moderate malnutrition, i.e., length and weight gain, functional outcome, immunity, and micronutrient status. Thus, there is an urgent need for studies that determine the impact of new or modified foods for treating moderate malnutrition in comparison to fortified blended foods and RUTF;
- The availability of RUTF is limited, and it is preferentially used for treating severe acute malnutrition;
- Milk appears to be an essential food that comes at a relatively high cost compared with staples and soybeans;
- The need for high-quality, nutritious foods for young children is not yet understood by all development partners, which limits commitment and funding.

Also, many of the modified or new foods or complementary food supplements are a new concept, both for consumers and for program implementers; thus, experience with their introduction, distribution, and

TABLE 9. Current response options for food-assistance programs to prevent and treat moderate and mild child malnutrition (wasting, stunting)

Intervention	Potential target groups	Considerations
Blanket supplementary feeding where the prevalence of malnutrition is high, i.e., ≥ 30% underweight or ≥ 15% wasted among children < 5 yr	All young children, especially those < 2 yr	Blanket supplementary feeding of all children < 2 yr is probably more effective than targeted supplementary feeding of underweight children < 5 yr [43]. When possible, improved fortified blended foods (which have better MN profile and, when possible, include milk powder, sugar, and oil) should be used. Alternative to be explored: staple for general population with additional complementary food supplements that provide 250–500 kcal for children 6–23 mo or 6–35 mo of age
Targeted supplementary feeding (appropriate where blanket feeding is not necessary due to lower malnutrition prevalence)	Children < 5 yr with moderate acute malnutrition	RUTF (500 kcal/day), new RUF commodity (500 kcal/day), complementary food supplements (250 kcal/day) + staple, improved fortified blended food with skimmed-milk powder, oil, and sugar, or standard fortified blended food mixed with sugar and oil
Home fortification using complementary food supplements such as MN powder, lipid-based nutrient supplements, and powdered complementary food supplements	Young children (< 5 yr) who cannot meet their needs from the general food ration or from the local diet that is within their means (i.e. available, affordable, acceptable)	Home-fortification commodities can be used when the quality of the primary diet is insufficient. Depending on the age group, prevailing malnutrition rate, and diet, a selection of the most appropriate complementary food supplements can be made
Cash transfers or vouchers to obtain nutritious foods or complementary food supplements	Vulnerable households in settings where food is available in markets and capacity for implementing programs exists	May be particularly suited for urban and periurban areas. To maximize impact on nutrition, collaboration with private sector should ensure availability of specific nutritious commodities to which the vouchers provide access. Eligibility for receiving a voucher can be linked to conditional cash transfer or food-for-work programs. Collecting vouchers and reimbursing shopkeepers requires reasonably functioning markets and administrative systems [44]

MN, micronutrient; RUF, ready-to-use food; RUTF, ready-to-use therapeutic food

use needs to be built.

It is important to note that the nutrient densities proposed by Golden [1] for specific nutrients are based on the assumption that the densities for other nutrients are also realized. For example, a higher intake of zinc than the RDA could affect copper metabolism except when copper intake is increased concurrently. Thus, when diets, with or without inclusion of special foods or complementary food supplements, meet the proposed requirements for some but not for other nutrients, this may have negative consequences for the status of the nutrient(s) of which too low amounts are consumed.

Recommendations

In order to move forward with the development and use of special food commodities for young and/or malnourished children, steps need to be taken in the following areas:

Use of new products

With the increasing development of products for preventing or treating different forms of malnutrition, there is a need for guidance on expected impact and on when, how, and for whom they can be used. The Consultation agreed that if it is expected that a new commodity has a better impact than currently used fortified blended food, it can be used in programs, provided that the product is acceptable to the beneficiaries, while at the same time its impact is studied under controlled circumstances (which could be in another location). Programs that use a new product should collect data to monitor the time needed for recovery of children with moderate malnutrition, when the product is used for treatment, or on the occurrence of new cases of malnutrition if it is used for prevention. Preferred comparison treatments for a study under controlled circumstances are the current fortified blended foods and RUTF; the latter is an adequately fortified, nutrient-rich therapeutic food. Outcome indicators should include indicators of physiological, immunological, cognitive, and body compositional recovery as well as simple weight gain (see also the Proceedings of the Consultation [47]).

Product development

Urgent questions and issues to be addressed for the development of new foods and complementary food supplements include the following:

» How much milk is required for optimal growth at different ages?
» Could a different combination of nutrients and active compounds achieve the same effect as milk powder?
» The use of phytase for human consumption needs to be permitted for young children also, and its impact on mineral bioavailability and digestibility should be assessed.
» The contents and effects of specific antinutrients need to be determined
» Food-composition tables need to include the contents of a wider range of micronutrients, active compounds, including fibers, and antinutrients.

Way forward for programs

Programs need to be adapted based on the newly proposed nutrient requirements for moderately malnourished children [1], the use of existing ingredients [2], the development of new foods and complementary food supplements (this article), improved understanding about which dietary changes to recommend and how [3], and increasing experience with production and use of new products in existing or modified programs. The following are some program-related issues that will need to be addressed in the near future:

» How can production capacity for new, especially ready-to-use, products be increased?
» How can the public and private sectors collaborate more effectively with regard to product development, production capacity, and distribution?
» Although the *why* of improved nutrition programming for young and for moderately malnourished children is clear, and the most suitable dietary options for different contexts are becoming clear, much experience needs to be gained with *how* to advocate for, design, and implement modified programs. This involves issues such as the following:
  – Advocacy at global and national levels about why modification of programs and commodities is proposed;
  – Program design: exchanging commodities or modifying programs?
  – Acceptability and awareness of new commodities among communities;
  – How are very similar commodities that are simultaneously distributed, such as corn–soy blend for general use and corn–soy blend with milk for young or malnourished children, used at the household level?
  – Can RUF for an individual child be provided with staples for general use by the family or should the RUF ration be doubled?
  – Evaluation of program data about the use and impact of new products.

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