WHO Technical Background Paper

Feeding of nonbreastfed children from 6 to 24 months of age in developing countries

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1. Introduction

Although breastfeeding is recommended for two years or more [1], there are circumstances under which this is not possible or desirable. In particular, the current epidemic of HIV/AIDS in parts of the developing world has forced policy makers to evaluate what type of infant-feeding recommendations to make to HIV-positive mothers, who may transmit the virus to their infants via breastmilk. The most recent international guidelines state that "when replacement feeding is acceptable, feasible, affordable, sustainable and safe, avoidance of all breastfeeding by HIV-infected mothers is recommended" [2]. When these conditions cannot be met, it is recommended that mothers breastfeed exclusively for the first few months and stop as soon as alternative feeding options become feasible. Other circumstances that may prevent a child from being breastfed include death or severe illness of the mother, or inability or lack of desire by the mother to breastfeed. Guidelines regarding replacement feeding from birth to six months for infants of HIV-positive mothers have been published elsewhere [2]. After the first six months, however, there is little information on how to construct a nutritionally adequate diet for the nonbreastfed child.

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The age range from 6 to 24 months is a critical period, when malnutrition and infection are particularly common in developing countries. For breastfed children, a set of recommendations in the form of 10 Guiding Principles was recently issued regarding complementary feeding within this age range [3]. Many of these Guiding Principles can also be applied to nonbreastfed children (Nos. 3, 4, 6, and 10). Others, however, need to be revised for nonbreastfed infants.

This document will cover appropriate feeding of nonbreastfed children from 6 to 24 months of age, with a focus on developing-country populations. The Guiding Principles that will be addressed include No. 5 (amount of food needed), No. 7 (meal frequency and energy density), No. 8 (nutrient content of foods), and No. 9 (use of vitamin-mineral supplements or fortified products). To address Nos. 8 and 9, linear programming (LP) techniques were used to develop diets that can meet nutrient requirements within this age range.

2. Use of animal milk for infants between 6 and 12 months of age

The issue of whether to include animal milk in the diet of infants under 12 months of age has been debated for decades. Most of the debate has focused on the use of whole cow's milk. The three main concerns are that cow's milk is low in iron (and the iron is not very well absorbed because milk also contains large amounts of bovine proteins and calcium, which inhibit nonheme iron absorption), can cause occult blood loss from the gastrointestinal tract, and has a high potential renal solute load (PRSL) [4, 5]. In the earlier part of the twentieth century, the use of whole cow's milk during infancy, even during the first four months of life, was common in the United States [5]. By the 1960s, concerns were raised by studies showing that cow's milk could cause occult gastrointestinal blood loss in infants with iron-deficiency anemia. The Committee on Nutrition of the American Academy of Pediatrics (CON-AAP) [6] stated in 1976 and 1983 that for nonbreastfed infants more than six months old, iron-fortified formula was the most convenient source of iron, but cow's milk together with regular use of iron-fortified cereals was acceptable. However, subsequent studies showing that blood loss could occur even in nonanemic infants, along with the recognition that the electrolytic iron in iron-fortified cereals is probably of low bioavailability, prompted the CON-AAP to recommend in 1992 that nonbreastfed infants be given iron-fortified formulas throughout the first year of life.

More recent papers on occult blood loss suggest that in the older infant the losses are very minor and not likely to affect iron status [7, 8]. The gastrointestinal response to cow's milk that causes blood loss decreases with age and disappears by 12 months [8]. Furthermore, there appears to be a dose-response relationship between the quantity of cow's milk and the amount of blood lost, such that only large volumes of milk would pose a significant risk between 6 and 12 months. Heat-treated cow's milk does not provoke blood loss [9], so use of boiled or evaporated milk would eliminate this risk. Thus, the risk of iron deficiency provoked by occult blood loss appears to be low and can be further reduced by heat treatment or restrictions on the amount of milk consumed. Although the low iron content and bioavailability of cow's milk can contribute to anemia, iron deficiency can be avoided by using iron supplements or fortified foods with adequate bioavailability.

The remaining issue is the potential renal solute load (PRSL) of cow's milk, which is considerably higher than that of breastmilk because of the higher content of protein and several minerals (sodium, chloride, potassium, and phosphorus). PRSL refers to the solutes coming from the diet that must be excreted by the kidney if none are used for growth and none are lost through nonrenal routes [4]. A high PRSL can lead to hypernatremic dehydration under conditions of water stress.

The potentially adverse consequences of feeding undiluted cow's milk to young infants have been recognized for more than 100 years [5]. This recognition led to various recipes for formulas that involved the addition of water and carbohydrate to the milk (for example, a typical evaporated milk formula used in the United States in the 1940s consisted of one can (13 ounces) of evaporated milk, 19 fluid ounces of water, and approximately 1 ounce of carbohydrate such as corn syrup) [5]. Over time, commercially prepared infant formulas were developed that came closer to approximating the nutritional composition of human milk, and these have become the standard for nonbreastfed infants in industrialized countries.

During the first six months of life, when infants usually receive nearly all of their nutrients from a single source (breastmilk or formula), it is important to ensure that the PRSL of that product is appropriate. However, when infants begin to consume a mixed diet, the risks of providing a product with a relatively high PRSL, such as undiluted cow's milk, can be avoided if a sufficient amount of fluid is included in the overall diet. The greatest danger from a high PRSL occurs when the child has diarrhea and is losing far more water than usual. Continued use of cow's milk (or other foods with a high PRSL) during diarrhea, without providing extra fluids, can exacerbate the situation. Thus, if cow's milk is a significant part of the diet, special attention needs to be paid to ensuring adequate hydration during illness. In section 3.6, this issue is revisited using information on the PRSL of the diets generated by LP.

3. Using linear programming (LP) to design diets for nonbreastfed children

3.1 LP

LP is a technique that can be used to develop diets that meet nutritional requirements at the lowest possible cost [10–12]. It has been used for decades for feeding domestic animals, but only recently has the technique been applied to human diets. Briefly, LP allows one to minimize any linear function of a set of variables (e.g., cost) while fulfilling numerous constraints (e.g., energy and nutrient requirements, maximum amount of each food that can feasibly be consumed). The solver function in Microsoft Excel can be used to run the program. For a given population, the only information needed is the list of locally available foods and their costs, and the typical amounts of each food consumed by children in the designated age range. In this report, the age ranges used for the LP analyses were 6 to 9, 9 to 12, and 12 to 24 months.

3.2 Methods used in this report

3.2.1 Food-availability scenarios

To develop dietary recommendations that could be applied under a wide range of circumstances, the LP analyses were conducted assuming several different scenarios regarding the availability and affordability of milk products:

» Commercial infant formula available
» Animal milk products available, but not infant formula
» No animal milk products available

Within each of these scenarios, LP runs were conducted both with and without the inclusion of other types of animal-source foods, such as eggs, chicken, meat, chicken liver, and fish. In all runs, iron, zinc, and calcium supplements were allowed to enter the solution if necessary (i.e., if no solution could be found without one or more of those supplements). The costs of these supplements were set artificially high in order to "force" the program to choose foods whenever possible, rather than supplements. In two other sets of runs (sections 3.5.2 and 3.5.3), a fortified, fat-based complementary food supplement (Nutributter) or a fortified corn-soy blend (CSB) flour was allowed to enter the solution. The composition of Nutributter and CSB used in these analyses is shown in table 1. In these runs, the cost of Nutributter was set somewhat high (US$0.10 per 20-g dose) to minimize the amount of Nutributter that was chosen. The cost of CSB was estimated to be US$0.04 per 100 g. In another set of runs (section 3.5.4), three different complementary food supplements—Nutributter; Foodlets, a multiple micronutrient developed by UNICEF; and Sprinkles—were each allowed to enter the solutions one at a time (the composition of each of these products is shown in table 1). In these runs, more realistic cost estimates for these supplements were used (US$0.06 per 20 g of Nutributter; US$0.03 per dose of Foodlets or Sprinkles) [13] so that an overall cost comparison of the resulting diets, and of the diets with CSB, could be made (it should be noted, however, that these three complementary food supplements are still undergoing research testing and are not yet widely available, and CSB is generally available only through food aid programs). Finally, in another set of runs (section 3.5.5), heat-treated expressed breastmilk was substituted for cow's milk to determine the nutritional feasibility of this option for HIV-positive mothers.

3.2.2 Datasets used to develop food lists and maximum amounts consumed

Datasets on the dietary intake of children between 6 and 15 months of age were available from five countries: Bangladesh [15], Ghana [16], Guatemala [17], Honduras [18], and Peru [19] (see details in table 2). The information from the latter three countries was combined to represent the Latin America region.

These datasets were used to determine the foods consumed most often by infants in that population and the maximum amount of each food ever consumed by any child in each of the countries. This information was used to develop the food lists to be used in the LP runs. To maximize the possibility of developing nutritionally adequate diets using local foods, nutrient-dense foods such as meat, chicken liver, and eggs were added to the food lists, even if they were only rarely consumed by a given population. Table 3 shows the food lists for each of the three regions represented. In general, the maximum amount of each food that was allowed to enter the LP solution was set at 90% of the maximum amount ever consumed by any child in any of the five countries. However, for some foods the maximum amount ever consumed was very low (< 20 g), so in these cases the maximum for the LP runs was set at 20 g. For eggs, the maximum was set at 50 g (one egg), given that it would not be feasible to recommend more than one egg per day in most circumstances.

Information on the costs of local foods in each country was also obtained (table 3). The LP runs were set up to minimize the total cost of each diet, using this cost information.

3.2.3 Food-composition data and bioavailability assumptions

Food-composition data were taken from the International Minilist [20] whenever possible. This database includes information on phytate content, which was used for estimating zinc bioavailability. When a given food was not available in the International Minilist, data were obtained from US Department of Agriculture (USDA) food-composition tables or the World Food Program [20]. For Ghana, the nutrient content of various recipes typically used for infant feeding was calculated using the USDA food-composition data.

The LP runs were structured to take into account the estimated bioavailability of iron, zinc, and calcium from the foods in each diet. The absorption of iron was assumed to be 6% from plant-source foods, 11% from animal-source foods (including milk, in which the bioavailability of iron is lower than in meats), and 8.5% from iron supplements. Zinc absorption was estimated based on the phytate-to-zinc ratio of the diet, using a nonlinear regression to smooth out the step function published by the Food and Agriculture Organization/World Health Organization/International Atomic Energy Agency (FAO/WHO/IAEA) [21]. The absorption of calcium was assumed to be 25% for legumes, roots or tubers, and grains, 5% for foods with high oxalate content (e.g., spinach), 45% for other fruits and vegetables, 32% for all other foods (including dairy products), and 30% for calcium supplements [22].

3.2.4 Constraints on nutrient intake

In each LP run, the solution had to meet several constraints regarding nutrient intake. First, the total energy content of the diet had to be equal to the energy requirements for each age range (615 kcal/day for 6–9 months, 686 kcal/day for 9–12 months, and 894 kcal/day for 12–24 months) [23]. Second, the fat content of the diet had to provide at least 30% of the energy. Third, each solution had to meet or exceed the recommended nutrient intake (RNI) for protein and nine selected micronutrients (vitamin A, thiamine, riboflavin, vitamin B_6, folate, vitamin C, calcium, iron, and zinc). These nine nutrients were selected because they were identified as potential "problem nutrients" for children 6 to 24 months of age [23]. Niacin was also identified as a potential problem nutrient, but it was not included as a constraint in the LP runs because of the difficulty of estimating the amount of niacin available via the conversion from tryptophan.

The RNI values chosen for this analysis were based on the latest WHO/FAO or Institute of Medicine (IOM) Dietary Reference Intakes recommendations

TABLE 1. Composition of complementary food supplements and corn-soy blend

Nutrient	Nutributter[a] (per 20 g)	Foodlets (per one dose)[b]	Sprinkles (per one dose)[c]	CSB[d] (per 100 g)
Energy (kcal)	108	0	0	376
Protein (g)	2.5	0	0	17.2
Fat (g)	7	0	0	6.9
Vitamin A (μg RE)	400	375	300	784
Thiamine (mg)	0.3	0.5	0	0.5
Riboflavin (mg)	0.4	0.5	0	0.5
Niacin (mg)	4	6	0	6
Vitamin B_6 (mg)	0.3	0.5	0	0.5
Vitamin B_{12} (μg)	0.5	0.9	0	1.0
Folic acid (μg)	80	150	150	300
Pantothenic acid (mg)	1.8	0	0	3.4
Vitamin C (mg)	30	35	50	40
Vitamin D (μg)	0	5	7.5	5
Vitamin E (mg)	0.4	6	0	8.7
Calcium (mg)	100	0	0	831
Copper (mg)	0.2	0.6	0	n/a
Iodine (μg)	90	50	0	57
Iron (mg)	9	10	12.5	17.5
Magnesium (mg)	16	0	0	174
Manganese (mg)	0.08	0	0	n/a
Phosphorus (mg)	82	0	0	206
Potassium (mg)	152	0	0	n/a
Selenium (μg)	10	0	0	n/a
Zinc (mg)	4	10	5	5
Phytate (mg)	83	0	0	877

RE, Retinol equivalent; n/a, not available.

a. Nutributter is a fortified, fat-based spread produced by Nutriset (Malauney, France). The composition shown here is for a version used in a trial on complementary feeding in Ghana, 2003-04. The ingredients include vegetable fat, peanut paste, dry skimmed milk powder, dry whey, maltodextrin, sugar, and vitamin/mineral complex.

b. As shown in Nestel et al. [13].

c. Current formulation (S. Zlotkin, personal communication).

d. Corn-soy blend [14].

TABLE 2. Studies from which dietary data were available for the linear programming runs

Country	Age range (mo)	*N*	No. of records/ child	Total no. of records	Dietary data collection
Bangladesh [15]	6–12	126	1	126	Weighed intake (by observer)
Ghana [16]	6–12	190	1–5	501	Weighed intake (by observer)
Guatemala [17]	6–15	305	1–6	1,552	Weighed intake (by observer)
Honduras [18]	6–9	127	1–6	706	Maternal recall
Peru [19]	6–12	127	1–6	739	Weighed intake (by observer)

[23], whichever was lower for a given nutrient (for the 6- to 12-month age interval). The lower value was chosen because most of the RNI values are based on “adequate intake” estimates, which may overestimate actual nutrient needs. Choosing the lower values also maximized the chance of finding a solution that met nutrient needs using local foods. To estimate the recommended amount of *absorbed* iron, zinc, and calcium, the relevant RNIs were multiplied by 0.1, 0.33, and 0.3, respectively (the bioavailability factors used in calculating the RNIs). Thus, the amounts of these nutrients to be provided by the LP solutions at 6 to 12 months were 0.93 mg of absorbed iron, 1.0 mg of absorbed zinc, and 81 mg of absorbed calcium. At 12 to 24 months, the respective amounts were 0.58, 1.0, and 150 mg.

TABLE 3. Foods included for each region, 90% of maximum amount consumed in grams in each region (90% max.), and costs used in linear programming runs

No.	Latin America	90% max.	$US/ 100 g	Bangladesh	90% max.	$US/ 100 g	Ghana	90% max.	$US/ 100 g
1.	Banana, raw, ripe	115	0.05	Banana (ripe)	115	0.03			
2.	Beef, medium fat	40	0.58				Beef, thin, roasted	40	0.19
3.	Bread, wheat, white	75	0.03	Bread	75	0.48	Bread, wheat, white	75	0.17
4.	Cassava root, white boiled	185	0.14				Cassava root, white boiled	185	0.09
5.	Chicken, mature, meat	95	0.59	Chicken	95	0.73	Chicken, mature, meat	95	0.65
6.	Crackers, salty or savory	20	0.48	Crackers	20	0.05			
7.	Egg, chicken, raw or cooked	50	0.20	Egg	50	0.10	Egg, chicken, raw or cooked	50	0.34
8.	Halibut, cooked, dry heat	75	0.37	Fish	75	0.22	Fish, smoked tuna	75	0.18
9.	Infant formula, lactogen, dry	140	3.00	Infant formula, dry	140	3.00	Infant formula, lactogen, dry	140	3.00
10.	Kidney bean, mature boiled	80	0.03	Lentil-cooked (dal)	80	0.05	Soybean, mature boiled	20	0.04
11.	Liver, chicken	35	0.59	Liver, chicken	35	0.83	Liver, chicken	35	0.18
12.	Mango, ripe, raw	80	0.03	Mango	80	0.17			
13.	Milk (cow), whole, not fortified	1,000	0.05	Milk (cow)	1,000	0.05	Milk (cow), whole, not fortified	1,000	0.05
14.				Onion	20	0.03	Onion, bulb, raw or boiled	20	0.06
15.	Orange, raw	180	0.07	Orange juice	180	0.11	Orange juice	180	0.03
16.	Papaya, ripe, raw	155	0.11	Papaya	155	0.13	Papaya, ripe, raw	155	0.12
17.	Pasta, wheat, white, cooked	70	0.03	Vermicelli	70	0.10			
18.	Peas, green, boiled	20	0.08				Cowpea, mature boiled	80	0.04
19.	Plantain, cooked	180	0.05				Plantain, cooked	180	0.05
20.	Potato, baked or boiled	125	0.07	Potato	125	0.02			
21.	Rice, white, unenriched, cooked	195	0.02	Rice (cooked)	195	0.03	Rice, white, unenriched, cooked	195	0.06
22.	Soybean oil	35	0.37	Oil	35	0.07	Palm oil, red, fresh	35	0.12
23.	Spinach, boiled	40	0.13	Spinach	40	0.02	Leaf, taro	40	0.06
24.	Squash, winter, yellow, cooked	130	0.09	Pumpkin	130	0.03			
25.	Sweet potato, tuber, orange	80	0.11				Yam, white, tuber, cooked	60	0.10
26.	Tomato, ripe or green	65	0.30				Tomato, ripe or green	65	0.06
27.	Tortilla, maize, lime-treated	75	0.07	Ruti (wheat tortilla)	75	0.03			
				Region-specific foods					
28.	Apple, raw	65	0.27				Banku	295	0.03
29.	Avocado	30	0.14				Corn dough	130	0.03
30.	Cabbage, boiled	55	0.07	Coconut (dry)	20	0.04	Fish, fresh mackerel	75	0.15
31.	Cantaloupe, raw	80	0.05	Guava	25	0.05	Groundnut soup	100	0.03

continued

TABLE 3. Foods included for each region, 90% of maximum amount consumed in grams in each region (90% max.), and costs used in linear programming runs *(continued)*

No.	Latin America	90% max.	$US/ 100 g	Bangladesh	90% max.	$US/ 100 g	Ghana	90% max.	$US/ 100 g
32.	Carrots, raw or boiled	85	0.08	Gur (cane sugar, brown)	20	0.03	Kenkey	100	0.03
33.	Cheese, hard, whole milk	20	0.35	Semolina	20	0.05	Kontomire stew	125	0.04
34.	Oats, rolled or meal, cooked	270	0.04				Koose	140	0.07
35.	Pineapple, raw	60	0.10				Okra soup (fresh or dried)	180	0.03
36.	Shortening, hydrogenated vegetable	35	0.10				Palm soup	160	0.03
37.	Squash, summer, cooked (fruit)	70	0.09				Sugar, white	45	0.03
38.							Tomato stew	100	0.03
39.							TZ (corn and millet porridge)	405	0.04

3.3 Results of initial LP runs with no limits on food choices

The initial set of LP runs was conducted without any limits on the number or types of different foods that could be included in a solution, focusing first on the age range from six to nine months. This was done for each of the three regions represented, and for each scenario described in section 3.2.1 (six combinations: formula + other animal-source food; formula but no other animal-source food; milk + other animal-source food; milk but no other animal-source food; no milk, but other animal-source food available; and no milk or other animal-source food). Micronutrient supplements were allowed, but these runs did not include Nutributter as an option. In Latin America and Bangladesh, solutions that did not include micronutrient supplements were possible only when formula was included. In Ghana, it was possible to get a solution that did not include micronutrient supplements if both milk and other animal-source foods were included. However, the solution had three different types of animal-source foods (besides milk): chicken liver, beef, and fish. This diet and most of the other diets that resulted from these initial LP runs were considered impractical because they generally incorporated multiple types of animal-source foods and a large number of different types of fruits and vegetables to be consumed all on the same day. In addition, many of these solutions included trivial amounts (< 5 g) of some foods, and did not include any of the staple foods for the region (e.g., no rice was included in the solutions for Bangladesh). Therefore, the programs were rerun after imposing additional constraints on the food choices.

3.4 Additional constraints on food choices

To achieve solutions that were more practical for translating into daily dietary recommendations, the following additional constraints were imposed:

Other than egg, only one other nonmilk animal-source food (meat, chicken, fish, or chicken liver) at a time was allowed. Thus, for solutions that included nonmilk animal-source foods, there were five options: egg only, egg + beef, egg + chicken, egg + fish, and egg + chicken liver. These five options were run both with and without the inclusion of infant formula or milk products. All resulting combinations were also run both with and without the inclusion of Nutributter.

The number of different fruits and vegetables allowed in a solution was restricted to two types of fruit and three types of vegetables at a time. These runs used the following choices: For Latin America, banana, papaya, spinach, avocado, and carrot in the first set of runs; in later runs, melon, mango, cabbage, and winter squash were substituted one at a time for banana, papaya, spinach, and carrot, respectively. For Bangladesh, guava, papaya, spinach, and pumpkin in the first set of runs; in later runs, banana was substituted for guava and mango was substituted for papaya. For Ghana, papaya, orange juice, tomato, taro leaf, onion, and okra soup.

If a solution included less than 5 g of any individual food, that food was deleted and the LP analysis was rerun. The only exception was oil, in which case the minimum was set to 5 g any time oil entered the solution.

The minimum amount of staple food was set at 30 g. The staple food was defined as rice (or rice products) in Bangladesh, TZ (a maize and millet porridge) in Ghana, and tortilla (or maize products) in Latin

America. In later runs in Latin America, bread or rice was substituted for tortilla as the “staple food” (i.e., a minimum of 30 g was imposed).

For options in which animal milk was included, the minimum amount of milk was set at 200 g.

Sugar was deleted as a food choice in all regions. Coconut was deleted as a food choice in Bangladesh (because its fibrous consistency may be inappropriate for infants), and oatmeal was deleted in Latin America (because oats are usually imported).

3.5 Results of LP runs with limits on food choices

3.5.1 Without complementary food supplements or fortified corn-soy blend (CSB)

When infant formula was allowed into the solution at 6 to 9 months and 9 to 12 months, the amount that entered ranged from 279 to 486 ml/day when other animal-source foods were included (except when chicken liver was part of the diet, when the amount of formula that entered decreased to 100 to 186 ml/day). When no other animal-source foods were included, the amount of formula selected was 407 to 543 ml/day.

When no infant formula was allowed into the solution, the results varied greatly, depending on the other foods in the diet. Tables 4 to 12 show the amounts of foods in each solution for six different scenarios: (1) dairy products (whole cow’s milk, and in Latin America, cheese) + egg + one other animal-source food; (2) dairy products + egg but no other animal-source food; (3) dairy products but no other animal-source food; (4) no animal-source food; (5) no animal-source food, but Nutributter included; and (6) no animal-source food, but CSB included. Each table represents a different region and one of the three age intervals. The first column shows the foods permitted to enter the solution, and the second column shows the maximum quantity that was allowed to enter (in grams of cooked food except for CSB, which is shown as the dry amount). The remaining six columns show the amounts of each food that entered the solution for each of the six scenarios above. This section will discuss the first four scenarios.

At six to nine months (tables 4–6), no solution was possible without the inclusion of an iron supplement. The amount of supplemental iron required ranged from 1.2 to 7.8 mg/day, depending on the amount and type of animal-source foods in the diet. When there was no animal-source food in the diet (scenario 4), supplemental calcium (19–113 mg/day) and zinc (0.6–1.5 mg/day) were also needed. The amount of supplemental calcium required depended on the region and the type of staple food chosen for Latin America (less calcium was required when tortillas were included, because the maize is treated with lime). When other animal-source foods were in the diet (scenarios 1 and 2), the amount of milk in the solution was approximately 200 ml/day (the imposed minimum) in Bangladesh, 200 to 345 ml/day in Ghana (the higher amount was needed for scenario 2), and 200 to 369 ml/day in Latin America (less milk was required when bread was the staple than when tortillas or rice were the staple). When no other animal-source foods were in the diet (scenario 3), the amount of milk in the solution was 340 ml/day in Bangladesh, 490 ml/day in Ghana, and 399 to 496 ml/day in Latin America. When egg was allowed (scenarios 1 and 2), the amount that entered was the maximum (50 g), except in Ghana when beef was included. The amount of meat, chicken, fish, or chicken liver in scenario 1 ranged from 30 to 75 g/day. For beef, fish, and chicken liver, the amount that entered the solution was generally the maximum allowed (40, 75, and 35 g/day, respectively). Grain products were “forced” into all solutions at a minimum of 30 g/day, but the amount that entered varied depending on the other foods in the diet. Legumes entered all solutions. Up to seven additional foods entered the solutions, usually including one fruit and one to three vegetables. Oil was added to almost all diets in Bangladesh but was required only for scenario 4 (no animal-source food) in Latin America and Ghana.

At 9 to 12 months (tables 7–9), the situation was similar. No solution was possible without the inclusion of an iron supplement. The amount of supplemental iron required ranged from 0.7 mg/day (in Ghana, scenario 1 with chicken liver) to approximately 5 to 7 mg/day (scenarios 2–4). When there was no animal-source food in the diet, supplemental calcium (5–117 mg/day) and zinc (0.7–1.5 mg/day) were also needed (except in Bangladesh, where no solution for scenario 4 was possible unless the maximum amount of spinach allowed was increased to 100 g; in this situation no supplemental zinc was needed). When other animal-source foods were in the diet, the amount of milk in the solution was approximately 200 ml/day in Bangladesh, 200 to 337 ml/day in Ghana, and 200 to 365 ml/day in Latin America. When no other animal-source foods were in the diet (scenario 3), the amount of milk in the solution was 339 ml/day in Bangladesh, 483 ml/day in Ghana, and 375 to 516 ml/day in Latin America. When egg was allowed, the maximum amount (50 g) always entered (except in Ghana when beef was included). The amount of meat, chicken, fish, or chicken liver in scenario 1 ranged from 28 to 75 g/day. Legumes entered all solutions. Oil was added to almost all diets in Bangladesh and Ghana, but was required only for scenario 4 (no animal-source food) in Latin America.

At 12 to 24 months (tables 10–12), iron supplements were not required in Ghana but were required for scenarios 2 to 4 in Latin America and all scenarios in Bangladesh except when chicken liver was included. The amount of supplemental iron required in those two regions was approximately 1 to 3 mg/day, considerably less than at 6 to 12 months. When there was no animal-source food in the diet, supplemental calcium (210–330 mg/day) and zinc (0.3–1.3 mg/day) were also needed. In Bangladesh, no solution for scenario 4 (no animal-source food) was possible unless the maximum amount of spinach was increased to 120 g. In Ghana, nonmilk animal-source foods did not enter the solutions (except when chicken liver was the option), but the amount of milk included in scenarios 1 to 3 was 339 to 351 ml/day. In Latin America and Bangladesh, the amount of milk in the solution was 200 to 352 ml/day when other animal-source foods were in the diet and 376 to 439 ml/day when no other animal-source foods were allowed. When egg was allowed, none entered in Ghana, but the maximum amount (50 g) entered in Latin America and Bangladesh except when chicken liver was included. The amount of meat, chicken, fish, or chicken liver in scenario 1 for Latin America and Bangladesh ranged from 20 to 75 g/day. Legumes entered all solutions. Oil was required for most scenarios in Bangladesh and for certain diets in scenarios

TABLE 4. Solutions for Latin America, 6–9 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–236	249–369	399–496	—	—	—
Cheese	20	0 (MPL) 20 (F)	20	20	—	—	—
Egg	50	50	50		—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 51–69	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Tortilla	75	0–61	0–30	0–30	75	75	30
Bread	75	0–30	0–31	0–30	0–30	41	14
Rice	195	0–30	0–31	0–30	0–30	0	0
Crackers	20	0	0	0	0–18	0	0
Pasta	70	0	0	0	0	0	0
Legumes							
Red beans	80	55–80	68–80	64–80	0–39	80	80
Roots/tubers/ plantain/cassava							
Plantain	180	0–24	0	0	0–6	0	0
Sweet potato	80	0–34	0	0	80	0	0
Cassava	185	0	0	0	0	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	40	40	40	40	0	40
Other vegetables							
Avocado	30	0–26	29–30	0–18	30	0	30
Carrot	85	85	85	85	85	83	76
Fruits							
Papaya	155	14 –35	0–32	28–30	155	0	0
Banana	115	0	0	0	0	0	0
Oil	35	0	0	0	12–13	10	11
Fe supplement (mg)		2.2–5.8	6.3–6.4	7.0–7.1	7.3–7.8	0	0
Ca supplement (mg)		0	0	0	9–28	0	0
Zn supplement (mg)		0	0	0	1.3–1.5	0	0.5
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

1, 3, and 4 in Latin America.

In Ghana, the solutions included three different types of legumes (groundnuts, soybeans, and cowpeas), whereas there was only one source of legumes in the diets for Latin America and Bangladesh. This may explain why nonmilk animal-source foods generally did not enter the solutions at 12 to 24 months in Ghana. With fewer types of legumes available, nonmilk animal-source foods would be needed at this age in Ghana.

One important consideration in the above LP analyses is the conversion factor used to estimate the amount of vitamin A obtainable from β-carotene in plant foods. The food-composition tables use a ratio of 6:1 for the conversion of β-carotene to retinol equivalents (RE), but recent data indicate that a ratio of 12:1 is more appropriate [24]. Thus, if all of the vitamin A in the LP solutions came from plant sources, the actual amount of usable vitamin A would be approximately half of the amount estimated by the program. This was not a concern for the LP solutions for Latin America or Bangladesh, because all of them (even those with no animal-source foods) included more than 800 RE of vitamin A (twice the RNI of 400 RE), and thus would have been adequate even if a ratio of 12:1 had been used. For Ghana, most of the LP solutions had less than

TABLE 5. Solutions for Bangladesh, 6–9 months

Food type	Max. grams per day	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	204	340	—	—	—
Egg	50	50	50	—	—	—	—
P, F, L							
Chicken	95	34	—	—	—	—	—
Fish	75	or 73	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	16
Rice	195	30	30	30	30	30	30
Crackers	20	0	6	0	20	20	0
Semolina	20	0	0	0	0	0	0
Pasta	70	0	0	5	0	0	0
Legumes							
Lentils	80	80	80	80	80	80	80
Roots/tubers/ plantain/cassava							
Potato	125	72–125	125	125	100	64	0
Spinach	40	40	40	40	100[b]	40	40
Other vegetables							
Pumpkin	130	130	130	130	130	130	130
Onion	20	0	20	20	20	20	20
Fruits							
Papaya	155	0	0	0	155	155	0
Guava	25	0	25	25	25	25	25
Oil	35	0–5	5	6	17	10	15
Fe supplement (mg)		2.5–5.7	6.2	6.9	5.6	0	0
Ca supplement (mg)		0	0	0	113	28	0
Zn supplement (mg)		0	0	0	0.6	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

b. Riboflavin limiting, no solution possible unless spinach maximum is increased.

800 RE of vitamin A. To evaluate actual vitamin A adequacy, the Ghana analyses were rerun after multiplying the vitamin A content of the plant source foods by 0.5. All of the solutions yielded identical diets to those shown in tables 10 to 12 and had more than 400 RE of vitamin A (adjusted). Thus, the diets in tables 4 to 12 are adequate in vitamin A even if a 12:1 conversion ratio for β-carotene is utilized.

Another important consideration in these analyses is the maximum amount of nonmilk animal-source foods allowed in scenarios 1 and 2. To optimize the ability to meet nutrient needs from local foods, the maximum amounts chosen (90% of the maximum amount consumed in any of the sites) were relatively high (40 g of beef, 75 g of fish, 95 g of chicken, 35 g of chicken liver, and 50 g of egg). Most infants in devel-

TABLE 6. Solutions for Ghana, 6–9 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	345	490	—	—	—
Egg	50	0 (M) 50 (PFL)	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 30	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	59–129	94	87	32	30	30
Corn dough	130	0	0	0	0	0	20
Banku /kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	80
Groundnut soup	100	0–39	0	0	100	100	100
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	0	20	0
Yam	60	0	7	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	40	40	40	40	40	22
Other vegetables							
Onion	20	0	0	0	20	20	0
Okra soup	180	0–21	0	0	180	20	47
Fruits							
Papaya	155	0	0	0	155	155	0
Orange juice	180	0	0	0	180	180	0
Tomato	65	65	65	65	65	0	0
Oil	35	0–5	0	0	5	0	1
Fe supplement (mg)		1.2–4.7	5.1	5.8	5.9	0	0
Ca supplement (mg)		0	0	0	39	0	0
Zn supplement (mg)		0	0	0	0.8	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

oping countries do not consume these quantities of animal-source foods. Among children under two years of age in the United States who consume these foods, the mean consumption of red meat (35 g), eggs (46 g), and organ meats (66 g) is similar to or greater than the maximum amounts allowed in the LP analyses, but the mean consumption of poultry (45 g) and fish (40 g) is considerably lower than the maximum allowed [25]. Thus, the diets for scenarios 1 and 2 may be unrealistic and might lead to an underestimation of the amount of milk needed if consumption of animal-source foods is less than the amounts that entered each solution. To evaluate this possibility, the LP analyses for these two scenarios were rerun using maximum amounts for nonegg animal-source foods set at the 75th percentile of consumption (for the site with the highest consumption of that food). These maximums were 14 g of beef, 38 g of fish, 20 g of chicken, and 21 g of chicken

TABLE 7. Solutions for Latin America, 9–12 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–300	200–365	375–516	—	—	—
Cheese	20	0 (MPL)14–20 (F)	20	20	—	—	—
Egg	50	50	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 48–78	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Tortilla	75	0–71	0–30	0–52	75	75	30
Bread	75	0–30	0–30	0–30	0–30	63	39
Rice	195	0–30	0–30	0–30	0–30	0	0
Crackers	20	0	0	0–20	0–20	0	0
Pasta	70	0	0	0	0	0	0
Legumes							
Red beans	80	77–80	80	80	29–80	80	80
Roots/tubers/plantain/cassava							
Plantain	180	0–90	0–49	0–64	0	0	0
Sweet potato	80	0–31	0–56	0–52	59–80	0	0
Cassava	185	0–7	0	0	0	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	4 0	40	40	40	0	40
Other vegetables							
Avocado	30	0–3	30	0–30	30	0	30
Carrot	85	85	85	85	85	79	55
Fruits							
Papaya	155	16–35	0–23	0–12	155	0	0
Banana	115	0	0	0	0	0	0
Oil	35	0–5	0	0	13–15	12	12
Fe supplement (mg)		2.2–5.5	5.9–6.0	6.6–6.7	6.5–7.4	0	0
Ca supplement (mg)		0	0	0	5–18	0	0
Zn supplement (mg)		0	0	0	1.4–1.5	0	0.5
Nutributter	20	—	—	—	—	20	—
CSB	60						60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

liver. The maximum for eggs was kept at 50 g because that amount is equivalent to approximately one egg. In these reanalyses, the amount of milk that entered remained approximately the same in Bangladesh, but there were changes in the amounts of some of the non-animal-source foods and a slight increase in the amount of iron supplement required. For Ghana, there was also very little change in the amount of milk that entered, but the amount of iron supplement required increased slightly. For Latin America, there was a small increase in the amount of milk (a difference of 0–81 ml, depending on which animal-source food was allowed), but the amount did not exceed 350 ml in any of the solutions; the amount of iron supplement required also increased slightly. The full amount of egg allowed (50 g) entered most of the solutions, so it could still be argued that these diets contain more animal-source foods than is realistic for developing countries. For this reason, scenarios 3 to 6 in tables 4 to 12 may be more appropriate in most circumstances.

3.5.2 With Nutributter

The LP runs that included Nutributter (at US$0.10 per 20 g) were done both with and without imposing the additional constraints described in section 3.4. Infant formula did not enter any of the solutions at any age.

TABLE 8. Solutions for Bangladesh, 9–12 months

Food type	Max. grams	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	203	339	—	—	—
Egg	50	50	50	—	—	—	—
P, F, L							
Chicken	95	44	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	5	0	75	0	9
Rice	195	30	30	30	30	30	30
Crackers	20	0–12	20	18	20	20	0
Semolina	20	0–9	0	0	0	0	0
Pasta	70	0–9	0	0	0	0	53
Legumes							
Lentils	80	80	80	80	39	80	80
Roots/tubers/ plantain/cassava							
Potato	125	121–125	125	125	6	122	0
Spinach	40	40	40	40	100[b]	40	40
Other vegetables							
Pumpkin	130	130	130	130	130	130	130
Onion	20	0–12	20	20	20	20	20
Fruits							
Papaya	155	0	0	0	155	155	0
Guava	25	25	25	25	25	25	25
Oil	35	0–6	5	6	17	12	17
Fe supplement (mg)		2.3–5.4	6.1	6.7	6.5	0	0
Ca supplement (mg)		0	0	0	117	25	0
Zn supplement (mg)		0	0	0	0	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

At 6–9 and 9–12 months, the amount of Nutributter that entered was close to the maximum allowed (19–20 mg/day). At 12 to 24 months, only 9 to 10 mg of Nutributter entered when milk products were allowed. When milk was allowed but no minimum amount was set, the amount of milk included in the solutions for Ghana was 121 ml at 6–9 and 9–12 months, and 343 ml at 12–24 months. For Latin America, the amount of milk included was 0 ml at 6–9 months, 36 ml at 9–12 months, and 259 ml at 12–24 months. For Bangladesh, the amount of milk included was 108 ml at 6–9 months, 111 ml at 9–12 months, and 335 ml at 12–24 months. Other animal-source foods did not enter the solutions when Nutributter was included (except for 7 g of cheese in Latin America at 6–9 months).

The second-to-last column of tables 4 to 12 shows

TABLE 9. Solutions for Ghana, 9–12 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200	337	483	—	—	—
Egg	50	12–50	50	—	—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 28	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 35	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	94–161	115	107	30	30	30
Corn dough	130	0	0	0	0	44	56
Banku /kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	75
Groundnut soup	100	0–52	0	40	100	100	96
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	57	0	0
Yam	60	0–19	7	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	40	40	0	40	40	0
Other vegetables							
Onion	20	0	0	0	20	14	0
Okra soup	180	0–21	0	0	180	180	0
Fruits							
Papaya	155	0	0	0	155	0	0
Orange juice	180	0	0	0	180	180	0
Tomato	65	65	65	65	65	0	0
Oil	35	0–5	5	5	5	0	6
Fe supplement (mg)		0.7–4.5	4.9	5.6	5.6	0	0
Ca supplement (mg)		0	0	0	30	0	0
Zn supplement (mg)		0	0	0	0.7	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

the solutions when Nutributter was included in a diet with no animal-source foods, applying the constraints described in section 3.4. At all ages, solutions were obtained without the need for additional iron or zinc supplements. Because the formulation of Nutributter used in these analyses included only a modest amount of calcium (100 mg per 20 g), in some situations the solution included additional calcium. At 6–9 and 9–12 months, this was necessary only in Bangladesh, where a small amount (25–28 mg) of additional calcium was included in the solution. At 12 to 24 months, it was necessary in all sites (115–249 mg of additional calcium), because the RNI for calcium at that age is much higher than at 6 to 12 months (500 vs. 270 mg).

The diets shown in the second-to-last column of tables 4 to 12 generally contain one or two types of grain products, legumes, occasionally tubers, one to three vegetables, zero to three fruits, and usually some additional oil. It should be noted that the maximum amount of Nutributter allowed (20 g) is a modest

TABLE 10. Solutions for Latin America, 12–24 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	200–230	277–312	423–439	—	—	—
Cheese	20	0–20 (all)	0–20	15–20	—	—	—
Egg	50	0 (L) 50 (MPF)	50		—	—	—
M, P, F, L							
Beef	40	40	—	—	—	—	—
Chicken	95	or 76–88	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 24–25	—	—	—	—	—
Grains							
Tortilla	75	5–75	0–30	0–33	75	75	30
Bread	75	0–75	0–30	0–30	0–30	0	75
Rice	195	0–30	0–30	0–30	0–30	0	0
Crackers	20	0	0	0	20	20	0
Pasta	70	0–70	0–40	0–70	0	0	70
Legumes							
Red beans	80	80	80	80	80	80	0
Roots/tubers/ plantain/cassava							
Plantain	180	0–180	178–180	130–180	0	0	0
Sweet potato	80	0	0	0	80	80	0
Cassava	185	0–114	0	0	16–64	0	0
Potato	0	0	0	0	0	0	0
Spinach	40	40	40	40	40	40	40
Other vegetables							
Avocado	30	0–30	30	30	30	30	0
Carrot	85	0– 85	85	85	85	83	31
Fruits							
Papaya	155	0–34	0	0	155	155	0
Banana	115	0	0	0	0–45	0	90
Oil	35	0–11	0	0–5	19–20	13	22
Fe supplement (mg)		0–0.5	1.0–1.1	1.7–2.0	1.8–2.0	0	0
Ca supplement (mg)		0	0	0	210–216	115	0
Zn supplement (mg)		0	0	0	1.3	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, meat; P, poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; tortilla, rice, or bread—30 g (only one of these three foods was forced per run). Food limits: fruits—only banana and papaya; vegetables—only spinach, carrots, and avocado.

amount and could be increased, especially in the second year of life. In addition, the amount of calcium included in the product could be increased. This has the potential to simplify the diets further.

3.5.3 With CSB

The LP runs with CSB allowed for a maximum of 60 g of this product, a typical ration size in feeding programs for infants and young children. The additional constraints described in section 3.4 were also imposed. In all sites, at all ages, the maximum amount of CSB entered the solutions. When milk was allowed, no more than the minimum amount of 200 ml of milk entered. When other animal-source foods were allowed, egg entered most of the solutions in Bangladesh (8–38 g) and Latin America (10–50 g), but not in Ghana. Other animal-source foods rarely entered in Bangladesh or Ghana, but cheese, fish, or chicken liver sometimes entered in Latin America. The last column of tables 4 to 12 shows the solutions when no animal-source food was allowed. In Latin America, these were generally similar to the solutions using Nutributter, except

TABLE 11. Solutions for Bangladesh, 12–24 months

Food type	Max. grams	Dairy + egg + P, F, or L[a]	Dairy + egg	Dairy, no egg or P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	273–352	310	376	—	—	—
Egg	50	22(L) 50 (P,F)	50	—	—	—	—
P, F, L							
Chicken	95	46	—	—	—	—	—
Fish	75	or 75	—	—	—	—	—
Liver (chicken)	35	or 20	—	—	—	—	—
Grains							
Bread	75	0–69	41	67	55	44	0
Rice	195	30	30	30	30	30	78
Crackers	20	20	20	20	20	20	20
Semolina	20	0–20	20	15	0	0	0
Pasta	70	0	0	0	70	70	0
Legumes							
Lentils	80	80	80	80	80	80	80
Roots/tubers/ plantain/cassava							
Potato	125	125	125	125	125	125	125
Spinach	40	40	40	40	120[b]	40	40
Other vegetables							
Pumpkin	130	0–130	130	130	130	130	130
Onion	20	0–20	20	20	20	20	20
Fruits							
Papaya	155	0–20	0	0	155	155	0
Guava	25	0–25	25	25	25	25	19
Orange juice	180	—	—	—	—	—	0
Banana	115	—	—	—	—	—	0
Oil	35	0–5	5	5	21	14	21
Fe supplement (mg)		0–0.9	1.6	2.2	0.5	0	0
Ca supplement (mg)		0	0	0	330	249	0
Zn supplement (mg)		0	0	0	0.3	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; rice—30 g. Food limits: fruits—only guava and papaya; vegetables—only spinach, pumpkin, and onions.

a. Meat was not included because it was never consumed by young children in the study population.

b. Riboflavin limiting, no solution possible unless spinach maximum is increased.

that the CSB substituted for some of the other grain products (and legumes at 12–24 months), spinach and avocado were added, and the CSB diets at 6–9 and 9–12 months required the addition of 0.5 mg of zinc. In Bangladesh, the solutions using CSB required fewer foods than the solutions using Nutributter (e.g., potato was deleted at 6–9 and 9–12 months, and papaya was deleted at all ages), but were otherwise similar. In Ghana, the solutions using CSB required less taro leaf, onion, okra soup, and orange juice than the solutions using Nutributter.

3.5.4 Cost comparisons with three different complementary food supplements and CSB

Nutributter is not the only product that could be added to home-produced foods to boost the nutritional

TABLE 12. Solutions for Ghana, 12–24 months

Food type	Max. grams per day	Dairy + egg + M, P, F, or L	Dairy + egg	Dairy, no egg or M, P, F, or L	No ASF	No ASF; Nutributter added	No ASF; CSB added
Milk	1,000	339–351	339	339	—	—	—
Egg	50	0	0	—	—	—	—
M, P, F, L							
Beef	40	0	—	—	—	—	—
Chicken	95	0	—	—	—	—	—
Fish	75	0	—	—	—	—	—
Liver (chicken)	35	or 14	—	—	—	—	—
Grains							
Bread	75	0	0	0	0	0	0
Rice	195	0	0	0	0	0	0
TZ	405	67–185	185	185	157	30	30
Corn dough	130	53–130	53	53	0	0	130
Banku/kenkey	295	0	0	0	0	0	0
Legumes							
Cowpeas	80	80	80	80	80	80	0
Groundnut soup	100	92–100	92	92	100	100	100
Soybeans	20	20	20	20	20	20	20
Roots/tubers/ plantain/cassava							
Cassava	185	0	0	0	48	135	0
Yam	60	0	0	0	0	0	0
Plantain	180	0	0	0	0	0	0
Taro leaf	40	0–40	40	40	40	40	6
Other vegetables							
Onion	20	0	0	0	20	20	0
Okra soup	180	0	0	0	180	180	105
Fruits							
Papaya	155	0	0	0	155	155	0
Orange juice	180	15–34	15	15	180	180	0
Tomato	65	0	0	0	65	65	0
Oil	35	0	0	0	7	5	17
Fe supplement (mg)		0	0	0	0	0	0
Ca supplement (mg)		0	0	0	251	147	0
Zn supplement (mg)		0	0	0	0.5	0	0
Nutributter	20	—	—	—	—	20	—
CSB	60	—	—	—	—	—	60

M, Meat; P, Poultry; F, fish; L, liver (chicken); ASF, animal-source foods; CSB, corn-soy blend. Amounts shown are per gram of cooked food, except for CSB, which is the dry amount. Food minimums: milk—200 g; TZ (corn and millet porridge)—30 g. Food limits: fruits—only orange juice, papaya, and tomato; vegetables—taro leaf, onion, and okra soup.

content of diets for infants and young children. Other options include crushable micronutrient tablets (called "Foodlets" by UNICEF) and Sprinkles, both of which can be mixed with foods for infants [13]. To compare these options, the LP runs were conducted with these three complementary food supplements allowed one at a time, using the cost estimates described in section 3.2.1. Table 13 summarizes the food costs for these diets and for the CSB diets in Latin America, Bangladesh, and Ghana using two scenarios: including milk (minimum of 200 ml/day) but no other animal-source food, and without any animal-source food. In the latter scenario, calcium and zinc supplements were allowed to enter the solution if needed, but the cost of these additional nutrients was not included.

When milk was included, the total cost of the diet was similar across the four options (Nutributter, Sprinkles, Foodlets, or CSB) at 6–9 and 9–12 months in Bangladesh and Ghana, ranging from US$0.18 to 0.24 per day, whereas in Latin America, the CSB option was more costly (US$0.31–0.33) than the other three options (US$0.24–0.26) at these ages. When no animal-source food was allowed, the total cost of the diet at 6–9 and 9–12 months was lowest with the Nutributter option in Latin America (US$0.26–0.27 vs. US$0.27–0.65 for the other options), but in the other two sites it was lowest with the CSB option (US$0.14–0.24 vs. US$0.30–0.54 for the other options). At 12 to 24 months, the CSB option was less expensive (US$0.17–0.29) than the other three options (US$0.29–0.83) in all sites, regardless of whether milk was included. It should be noted that in Bangladesh, no solution could be reached for the "no animal-source food" scenario with the Sprinkles or Foodlets options unless the maximum amount of spinach allowed was increased to 100 g (this was not the case for the Nutributter or CSB options). It should also be kept in mind that the costs shown in table 13 are rough estimates and could vary greatly depending on changes in local food costs. The choice of which option is most appropriate in a given situation will depend not only on cost, but also on availability and acceptability.

3.5.5 LP runs with heat-treated expressed breastmilk

For HIV-positive mothers, one option is to express their breastmilk, use heat treatment to inactivate HIV, and feed the treated milk to their infants. This may be a more practical option after six months, when milk is no longer the sole source of nutrients, than during the first six months, when sustained expression of sufficient quantities of milk may be difficult. Expressed breastmilk is a readily available, less costly option than commercial infant formula or cow's milk. To evaluate the types of foods that would be needed to complement expressed breastmilk, the LP runs for 6–9 and 9–12 months were repeated with heat-treated breastmilk as an option instead of cow's milk. The nutrient composition of human milk may be altered by heat treatment, but preliminary data suggest that the changes are minor except for vitamin C concentration, which appears to be reduced by about 20% [26]. Thus, for these LP runs, the composition of the human milk was assumed to be similar to that of milk from well-nourished women [27], but with the concentration of vitamin C reduced by 20%. The cost of human milk was set at US$0.01 per 100 ml, to allow for fuel costs for heat treatment (by comparison, the cost of cow's milk was US$0.05 per 100 ml). The amount of expressed breastmilk allowed into the LP solution was constrained by using a minimum of 200 ml/day and a maximum of 400 ml/day.

The results of these LP runs were similar to those using cow's milk, although different foods were sometimes chosen and the amounts varied somewhat. The amount of supplemental iron required was somewhat higher with breastmilk than with cow's milk, due to the lower iron content of human milk (0.3 mg/L, compared with 1.0 mg/L for cow's milk). Similarly, for scenarios that included little or no other animal-source food, some of the solutions included a small amount of zinc or calcium supplement when breastmilk was used but not when cow's milk was used. This is because the zinc and calcium concentrations in human milk are lower than those in cow's milk (zinc 0.9 vs. 4.0 mg/L, and calcium 280 vs. 1,150 mg/L, respectively). The amount of breastmilk that entered was approximately 200 ml in Latin America, 300 to 400 in Bangladesh, and 200 to 300 in Ghana. In Latin America less breastmilk than cow's milk entered the solutions for the scenarios that included no other animal-source food or egg as the only other animal-source food, whereas in Bangladesh more breastmilk than cow's milk was used for most options. In Ghana, the amount of breastmilk that entered varied depending on the dietary scenario.

Thus, a nutritionally adequate diet can be designed using heat-treated expressed breastmilk and appropriate complementary foods plus an additional source of iron (as is true for diets that include cow's milk). Although these LP runs do not demonstrate an advantage of breastmilk over cow's milk at this age with regard to the 12 nutrients considered in these analyses, they do not take into account all of the nutritional differences that may have functional consequences (e.g., certain fatty acids), nor the non-nutritive benefits of human milk (e.g., anti-infective properties, although there is little information on whether, or the extent to which, breastmilk from an HIV-infected woman protects her child from other infections) [28]. The cost of the overall diet is likely to be considerably lower if expressed breastmilk is used in place of cow's milk, and if no animal milk is available at all, the inclusion of expressed breastmilk is likely to significantly enhance dietary quality.

TABLE 13. Cost comparisons of diets including Nutributter, Sprinkles, Foodlets or corn-soy blend (US$)

Location	Nutributter	Sprinkles	Foodlets	Corn-soy blend
6–9 mo				
With milk				
Latin America	0.25	0.24	0.24	0.31
Bangladesh	0.24	0.20	0.18	0.21
Ghana	0.23	0.21	0.21	0.20
Without milk				
Latin America	0.26	0.65	0.65	0.27
Bangladesh	0.40	0.40	0.38	0.22
Ghana	0.47	0.49	0.49	0.14
9–12 mo				
With milk				
Latin America	0.26	0.26	0.25	0.33
Bangladesh	0.22	0.21	0.19	0.21
Ghana	0.23	0.22	0.22	0.21
Without milk				
Latin America	0.27	0.65	0.65	0.49
Bangladesh	0.41	0.42	0.42	0.24
Ghana	0.30	0.54	0.54	0.12
12–24 mo				
With milk				
Latin America	0.32	0.40	0.37	0.25
Bangladesh	0.29	0.33	0.33	0.19
Ghana	0.30	0.34	0.33	0.21
Without milk				
Latin America	0.79	0.82	0.83	0.29
Bangladesh	0.49	0.54	0.50	0.19
Ghana	0.64	0.62	0.60	0.17

3.6 Evaluation of potential renal solute load (PRSL) and extra fluid needed

The diets resulting from each of the LP solutions described in sections 3.5.1 and 3.5.2 were evaluated further for their PRSL and water content. PRSL was calculated using the following equation [4]:

$$\text{PRSL} = \text{Na} + \text{Cl} + \text{K} + \text{P} + (\text{protein} / 175)$$

(PRSL in milliosmoles; Na, Cl, K, and P in millimoles; protein in milligrams)

Because the Cl content of most foods is not listed in food-composition tables, Cl was estimated by multiplying the Na content by 1.5.

Across all age groups and sites, PRSL ranged from a low of 124 mOsm to a high of 461 mOsm, and was generally higher for diets that included nonmilk animal-source food. By making certain assumptions about urine concentration and the amount of nonrenal water loss expected, these PRSL values can be used to estimate the amount of water required from the total diet. These calculations are based on the following equation [4]:

$$C_{\text{urine}} = \text{RSL}_{\text{est}} / [W_f - W_e]$$

where C_{urine} is urinary concentration (mOsm/L), RSL_{est} is renal solute load (mOsm/day), W_f is water intake (L/day), and W_e is extrarenal water loss (L/day). RSL is generally less than PRSL because of the use of solutes for growth. To be conservative, PRSL was substituted for RSL in the above equation when solving for W_f. This results in the following equation:

$$W_f = [\text{PRSL}/C_{\text{urine}}] + W_e$$

The renal concentrating ability (C_{urine}) of an infant at about nine months of age is estimated to be 1,100 mOsm/L [4], but to allow for a margin of safety a value of 700 mOsm/L was used. Thus, the first part of the above equation [$\text{PRSL}/C_{\text{urine}}$] would range from 0.18 to 0.66 L/day (180–660 ml/day) for the range of PRSL values observed. W_e can be calculated based on assumed body weight. Under normal climatic conditions, W_e is about 60 ml/kg/day [4]. Based on estimated body weights of 7.5 kg at 6 months, 8.5 kg at 9 months, 9.75 kg at 12 months, and 12.3 kg at 24 months, W_e would be 480 ml/day at 6–9 months, 548 ml/day at 9–12 months, and 662 ml/day at 12–24 months.

Using the above equation, table 14 shows the estimated total water needs of nonbreastfed children in each age interval, based on either a low- or a high-PRSL diet. Under normal climatic conditions, total water needs are 690 to 900 ml/day with a low-PRSL diet and 1,010 to 1,210 ml/day with a high-PRSL diet. The amount of fluid coming from the diet can be subtracted from the total amount of water needed (based on each diet's PRSL) to estimate the amount of extra fluids required in each dietary scenario. The water content of these diets was 220 to 560 ml/day for the low-PRSL diets and 510 to 740 ml/day for the high-PRSL diets. The estimated net amount of extra water needed is 470 to 500 ml/day at 6–9 months, 450 to 530 ml/day at 9–12 months, and 340 to 470 ml/day at 12–24 months. This fluid can be provided as plain water or other beverages, or it can be used to make a porridge from the rice and/or other foods in the solution.

Under hot conditions, extrarenal water losses increase. If we assume that they are doubled under tropical conditions, the above equation can be applied using a value for W_e of 960 ml/day at 6–9 months, 1,096 ml/day at 9–12 months, and 1,324 ml/day at 12–24 months. This results in an estimate of the extra fluid to be incorporated into the diet of 950 to 980 ml/day at 6–9 months, 990 to 1,080 ml/day at 9–12 months, and 1,000 to 1,130 ml/day at 12–24 months (table 14).

Extrarenal water losses during diarrhea can be two to three times greater than normal, with the resulting total water need being increased accordingly. Fever can also increase extrarenal water losses. In such circumstances, it is essential that extra fluids be provided in addition to the water that would be coming from the normal diet. If the infant refuses the quantity of water needed, it may be necessary to restrict the intake of foods that are high in PRSL during illness. The foods with the highest PRSL in these sites were fish, cheese, chicken, beef, and chicken liver.

3.7 Evaluation of protein quality

Although the LP analyses were set up to ensure that the total amount of protein in each solution was adequate, they did not include individual amino acid requirements. This is partly because of uncertainty about amino acid requirements during infancy and early childhood [29]. For the diets in tables 4 to 12 that included animal-source foods (scenarios 1–3), the total amount of protein ranged from 24 to 52 g/day (14%–30% of energy), which is approximately two to five times the amount needed. Given that these diets included animal protein and that the total amount of protein was generous, there is very little risk of inadequate intake of individual amino acids.

The diets that could be more problematic are those without animal-source foods (scenarios 4–6 in tables 4–12). The total amount of protein in these diets ranged from 14 to 26 g/day. All of these diets included both grains and legumes, which enhances protein quality. Nonetheless, it is possible that some of them would provide less than the desired amounts of certain essential amino acids. Inspection of these diets suggested that the potentially limiting amino acids are lysine, sulfur-containing amino acids (methionine + cysteine), and tryptophan. To evaluate amino acid adequacy, the total amounts of these amino acids provided by each of the diets lacking animal-source foods were calculated and compared with recommended amino acid intakes for each age interval [30]. The results indicated that all of the diets were adequate in these amino acids, with one exception: the "no animal-source food" (without Nutributter) option for Latin America at six to nine months, which was short in lysine (630 mg/day, with tortillas as the staple grain, compared with the recommended amount of approximately 676 mg/day). This diet was also the lowest in total protein (14 g/day), with all other diets containing at least 17 g/day. Thus, nearly all of the options presented in tables 4 to 12 have adequate protein quality.

TABLE 14. Estimated water needs of nonbreastfed children (ml/day)

		Normal climate			Hot climate		
Age (mo)	PRSL[a]	Total water needed	Amount from foods	Extra water needed	Total water needed	Amount from foods	Extra water needed
6–9	Low[b]	690	220	470	1,170	220	950
	High[c]	1,010	510	500	1,490	510	980
9–12	Low[b]	760	310	450	1,300	310	990
	High[c]	1,080	550	530	1,630	550	1,080
12–24	Low[b]	900	560	340	1,560	560	1,000
	High[c]	1,210	740	470	1,870	740	1,130

a. PRSL, Potential renal solute load.
b. Based on the average of the lowest PRSL observed in each site at this age.
c. Based on the average of the highest PRSL observed in each site at this age.

4. Meal frequency and energy density

The number of feedings required depends on the overall energy density of the diet. Theoretical estimates of required meal frequency and energy density can be calculated from the total amount of energy required, assuming a gastric capacity of 30 g/kg body weight/day [23]. To meet the needs of nearly all children, 2 SD is added to the average age-specific total daily energy requirements. Table 15 shows the minimum number of meals required with three different estimates of energy density (0.6, 0.8, and 1.0 kcal/g). At the lowest energy density (0.6 kcal/g), five or six meals per day would be needed. This decreases to approximately four meals per day when energy density is at least 0.8 kcal/g, and to approximately three meals per day when energy density is at least 1.0 kcal/g. If a child typically consumes amounts that are less than the assumed gastric capacity at each meal, meal frequency would need to be higher than the values in table 15.

Conversely, the minimum dietary energy density required depends on meal frequency. Table 15 shows that the minimum energy density is about 0.65 kcal/g when there are five meals per day, 0.75 kcal/g when there are four meals per day, and 1.0 kcal/g when there are three meals per day.

These estimates provide a margin of safety because 2 SD has been added to the average energy requirement. Thus, not all children will need the number of meals shown in table 15. Since it is not possible to know which children have higher or lower energy requirements, caregivers should be attentive to the child's hunger cues when judging how often and how much to feed the child.

5. Review of experience with feeding nonbreastfed children

5.1 Replacement feeding of infants of HIV-positive mothers

Recent experience with replacement feeding of infants of HIV-positive mothers has reinforced concerns about the risks associated with bottle feeding of animal milks or infant formulas in developing countries. For example, in a study of 148 infants of HIV-positive mothers in India [31], the hospitalization rate during the follow-up period from birth to about 13 weeks was 0 among breastfed infants vs. 0.093 per 100 person-days in the replacement-fed infants ($p < .0001$). Four infants died, all of whom were replacement fed. In that setting, replacement feeding usually consisted of "top feeding," which is done with animal milk (cow, goat, or buffalo) diluted with water. Provision of ready-to-feed infant formula and instructions in its use could certainly reduce the risk of contamination and associated morbidity and mortality. However, in most situations contamination of milk fed by bottle is widespread. In periurban Peru, for example, 35% of bottle nipples tested positive for *Escherichia coli* [32], and in a semiurban slum in India, 54% of milk samples were contaminated by bacteria [33].

Aside from the issue of contamination, there has been concern about the nutritional adequacy of replacement diets. In formative research in Zambia to develop recommendations on replacement feeding, it was found that diets for infants over six months of age were nutritionally inadequate, even with breastmilk included, and that removing breastmilk would worsen the situation (E. Piwoz, personal communication).

Although some clinical and operational research

TABLE 15. Energy requirements, minimum meal frequency, and minimum dietary energy density for nonbreastfed children 6–24 months of age

Requirement	6–9 mo	9–12 mo	12–24 mo
Average energy requirement (kcal/day)	615	686	894
Energy requirement + 2 SD (+ 25%)	769	858	1,118
Functional gastric capacity (g/meal), based on 30 g/kg body weight	249	285	345
Number of meals required for given energy density			
0.6 kcal/g	5.1	5.0	5.4
0.8 kcal/g	3.9	3.8	4.1
1.0 kcal/g	3.1	3.0	3.2
Minimum energy density (kcal/g) required for given daily meal frequency			
3/day	1.03	1.00	1.08
4/day	0.77	0.75	0.81
5/day	0.62	0.60	0.65

studies have described the difficulties associated with implementing replacement feeding, few have reported on the micronutrient status of infants and young children in these studies or the association between nutritional status and the type of replacement feeding adopted. Nor is there clarity regarding the provision of micronutrient supplements to children in programs for the prevention of postnatal mother-to-child transmission of HIV infection (PMTCT).

To gather information on these issues, 10 research groups that are either involved with clinical PMTCT studies or are supporting operational programs in some capacity in eight countries in sub-Saharan Africa (Botswana, Côte d'Ivoire, Kenya, Malawi, South Africa, Uganda, Zambia, and Zimbabwe), were asked four questions regarding their study or program protocols:

» What replacement milk or food is recommended as an initial alternative to breastfeeding or after breastfeeding stops (especially after six months of age), and what support is offered?
» Are micronutrients offered to any children in the PMTCT study or program, and if so, what criteria are used to indicate that a child should receive supplements?
» What is the composition of the supplement, and how was this supplement chosen?
» What are the study or program recommendations regarding iron supplements for HIV-exposed infants, and what protocols are used for managing anemia?

The information obtained from those who responded (see Acknowledgments) is summarized below.

5.1.1 Replacement milk or food recommended and support offered

Research groups in Botswana, Côte d'Ivoire, Kenya, South Africa, and Zambia recommended and provided commercial infant formula as a breastmilk substitute for infants up to 12 months; some groups also provided bottles and teats or cups and also pots for sterilizing bottles. The national PMTCT programs in Botswana and South Africa provide infant formula to HIV-infected women for 12 and 6 months, respectively. In South Africa, a mother can avail herself of this supply any time in the child's first year of life, so that she may consider a period of exclusive breastfeeding and then use commercial infant formula to facilitate the transition from breastfeeding. In contrast to the national PMTCT programs, research groups in Côte d'Ivoire, Kenya, and Zambia provide free infant formula for varying periods. In Zambia, mothers participating in a study specifically designed to investigate the feasibility and the nutritional and morbidity consequences of early and abrupt cessation of breastfeeding are given infant formula along with a locally developed, nutrient-enriched cereal blend for three months to provide a nutritious diet when infants are weaned from breastmilk around four months of age.

In Malawi, Uganda, and Zimbabwe, research groups generally followed the national PMTCT protocols, which advocated exclusive breastfeeding unless the mother is able to purchase commercial infant formula herself and has the additional resources to safely prepare and store milk. After the infant is six months of age, full-cream unmodified cow's and goat's milk are also recommended. In Malawi, mothers participating in the research study are provided with the equivalent of 75 g/day of a locally produced, nutrient-fortified, ready-to-use food for infants made from peanuts, powdered milk, cooking oil, sugar, and a micronutrient premix.

Specific counseling on infant-feeding practices, including appropriate complementary feeding, is provided by all groups and programs. The quality, focus, and intensity of this counseling vary greatly, however, depending on the resources available.

5.1.2 Use of micronutrient supplements in PMTCT programs

National PMTCT protocols in each of the countries recommend vitamin A supplements every six months to all infants as part of the Integrated Management of Childhood Illness (IMCI) program. The South Africa PMTCT program also provides a multivitamin supplement containing vitamin A (900 μg), vitamin C (30 mg), vitamin B_1 (1.65 mg), vitamin B_2 (1.32 mg), vitamin B_6 (1 mg), niacin (11 mg), and vitamin D (300 IU/5 ml) to all HIV-exposed infants. The rationale for this was that infected infants would probably benefit, although there was no evidence base for this recommendation and there are no explicit recommendations regarding nonbreastfed infants, especially after six months of age. In a research program in Botswana to study the effect of an antiretroviral regimen given to breastfed infants, a comparable multivitamin preparation (vitamin A 2,330 IU, vitamin D 200 IU, thiamine 1 mg, riboflavin 1.2 mg, pyridoxine 0.5 mg, nicotinamide 5 mg, vitamin C 35 mg, and vitamin B_{12} 2.5 μg/5 ml) is recommended for all breastfed infants to avoid nutritionally related hematological abnormalities that might otherwise be attributed to the antiretroviral regimen.

In a research program in Malawi also investigating the effect of an antiretroviral regimen for HIV-infected mothers and/or their infants, a nutrient-rich, ready-to-use food is provided to infants who are rapidly weaned. The daily quantity of this food is designed to provide vitamin A (683 μg), vitamin C (40 mg), vitamin B_1 (0.5 mg), vitamin B_2 (1.4 mg), vitamin B_6 (0.5 mg), vitamin B_{12} (1.4 μg), folic acid (158 μg), pantothenic acid (2.3 mg), and niacin (4.0 mg), as well as Ca (240 mg), P (296 mg), K (833 mg), Mg (69 mg), Zn (10.5 mg), Cu (1.3 mg), and Fe (8.6 mg). For most nutrients, this formulation was based on replacing the nutrients that breastmilk would otherwise provide to infants 6 to 12 months of age. The product was already available in Malawi and had been formulated as part of the protocol for the treatment of children with severe malnutrition. It had been found to be well tolerated and safe in this setting.

In Zimbabwe, the PMTCT protocol advocates providing "multivitamins" to nonbreastfed infants receiving modified animal milk. However, these are not generally available, and locally manufactured, commercially available multivitamin preparations contain only vitamin A (2,000 IU), vitamin B_1 (1 mg), vitamin B_2 (1 mg), vitamin C (30 mg), and nicotinamide (7 mg/ 5 ml). Externally supported programs provide the same preparation to infants found to have growth faltering. In the Zambia Exclusive Breastfeeding study, micronutrients are provided via commercial infant formula and by a nutrient-enriched cereal blend containing vitamin A, vitamin E, vitamin C, vitamin D, vitamin B_1, vitamin B_2, vitamin B_3, vitamin B_6, folate, vitamin B_{12}, zinc sulfate, ferrous fumarate, magnesium, and iodine. This was developed by the Zambian National Institute for Scientific and Industrial Research in collaboration with the US Department of Agriculture as a complete replacement diet and is made from locally available foods. It is reportedly highly acceptable to mothers and is easy to prepare. No other supplements are provided in the national PMTCT program.

5.1.3 Use of iron supplements for HIV-exposed infants and management of anemia

None of the PMTCT protocols had an explicit recommendation for iron supplementation before or after the age of six months, regardless of whether the child had been breastfed, abruptly changed from breastmilk to another replacement feed, or replacement fed from birth; each deferred to national protocols or made no comment at all. In the Malawi research project, hemoglobin is tested at all follow-up visits, and adverse events are graded according to age (< 3, 3, or > 3 months) and severity. Iron supplements are not routinely given, since the ready-to-use food (RTUF) is fortified with iron.

National protocols generally recommended oral iron (6 mg of elemental iron/kg/day) with or without folate or multivitamins for treating mild to moderate clinical anemia, preferably with biochemical evidence of iron deficiency; transfusion is generally recommended if hemoglobin drops below 60 g/L. In Zimbabwe, preterm or low-birthweight infants are supposed to receive vitamin D and folate for three months from birth, and iron supplements from one to three months of age. Other countries reported using IMCI guidelines, which include dietary recommendations to improve iron intake and prevention of malaria; prophylactic iron supplementation is recommended in Uganda, though implementation is not always effective.

5.1.4 Need for consistent guidelines and further research

Respondents to the above questions were uniformly interested in learning about the approach of other groups. The WHO technical group on HIV and Nutrition highlighted the need to identify the daily requirements and safe limits for micronutrients in HIV-infected adults and children [34]. Even if a child is not infected with HIV, the likelihood of micronutrient deficiencies during this age period is high. Thus, there is a need for consistent guidelines regarding the types and amounts of fortified products or supplements that are recommended for nonbreastfed children. Research on products that are safe to use in developing-country settings is particularly important. For example, a South African food that may be useful in feeding nonbreastfed infants is a fermented cow's milk product that does not require refrigeration. Although milk products are generally low in iron, it may be possible to fortify such a product for use as a lower-cost, potentially safer alternative to commercial infant formula.

5.2 Adaptation of products used for malnourished children

Although there are published guidelines and formula recipes (e.g., F100 for feeding children with serious infections or severe malnutrition [35]), these are not directly applicable to nonbreastfed children in general. This is because the energy and protein needs of recovering severely malnourished children are much higher than normal, and those who are recovering from serious infections need special diets to minimize adverse reactions such as diarrhea induced by temporary lactose intolerance. Furthermore, the formulas recommended, such as F100, are not as useful for home-based feeding in contaminated environments because they provide an excellent growth medium for pathogenic bacteria.

An earlier version of the Nutributter product described herein (called ready-to-use food, RTUF) was originally developed as an alternative to the F100 formula for rehabilitation of severely malnourished children (after the initial phase of treatment). The advantages of RTUF are that it is resistant to bacterial contamination because it contains no water, can be eaten directly by the child without the addition of water, and has a very high energy and nutrient density. In a recent randomized trial comparing the efficacy of RTUF with that of the F100 formula fed to malnourished children 6 to 36 months of age in a clinical setting in Senegal, the RTUF group had significantly greater daily energy intake and weight gain and a shorter duration of rehabilitation than the F100 group [36]. This demonstrated that a product such as Nutributter can be successfully used to promote weight gain. The RTUF product is now being used for malnourished children in Malawi, and as mentioned above, the same program recently began trying it for children of HIV-positive mothers in the community, because infant formula is considered too risky. So far, there have been no major logistical or acceptability problems in using it, even for children younger than 12 months. A peanut-free version is now ready for field testing (André Briend, personal communication).

In the above trials, a relatively large amount of RTUF was fed, and it was consumed directly from the sachet rather than being mixed with other foods. For severely malnourished children who require very high energy intake, this may be the best strategy, but for nonbreastfed children in general, it would be less expensive to use a small amount of the product as a supplement (either eaten alone or mixed with other foods). The LP runs described in section 3.5.2 indicate that 20 g of Nutributter is generally sufficient in a diet that does not contain animal-source foods, as long as other nutritious foods, such as fruits and vegetables, are available. When the types of foods are even more limited, a larger quantity of Nutributter can be used to satisfy nutrient needs.

The total fluid needs of children fed RTUF or Nutributter should be kept in mind, since the product does not contain water. Fluid needs can be partially satisfied by including animal milks (with due attention to hygiene), but they can also be met by providing plain boiled water or preparing porridges or soups from the foods listed in the diets shown in tables 4 to 12.

6. Conclusions and limitations

The literature reviewed and the results of the LP runs described above suggest the following conclusions:

1. Animal milk, such as undiluted whole cow's milk, can be fed to infants after six months of age, provided that iron supplements or iron-fortified foods with adequate bioavailability are consumed and the amount of fluid in the overall diet is adequate (see section 3.6). Animal milk, such as cow's milk, is a good source of several key nutrients. When the diet does not include fortified foods or supplements, the amounts of milk needed daily range from less than 200 to approximately 370 ml if other animal-source foods are included in the diet, and from approximately 300 to 500 ml if they are not. Raw milk (i.e., not boiled or pasteurized) should be avoided because of the risk of disease transmission. Fermented milk products (e.g., yogurt) hold promise for reducing the risk of illness due to contamination, since they are more resistant to bacterial growth and can be fed more easily by spoon or cup rather than by bottle, as compared with nonfermented liquid milk. Commercial infant formula is an option when it is available and affordable, can be safely used, and provides a nutritional or other advantage over animal milk (e.g., when fortified food products or supplements are not available or are more expensive). In these circumstances, the daily amount of formula needed at 6 to 12 months of age is approximately 280 to 500 ml if other animal-source foods are included in the diet and approximately 400 to 550 ml if they are not.

2. To meet nutrient needs, animal-source foods other than milk are also needed unless multiple micronutrient supplements or fortified products are provided. The daily amounts included in the LP analyses were 50 g of egg (one egg) and 14 to 75 g of meat, poultry, fish, or chicken liver.

3. Iron supplements or fortified products are needed in nearly all situations, in daily amounts ranging from 1 to 8 mg Fe, depending on the age range and other foods in the diet. If animal-source foods are not available, supplements of zinc (0.3–1.5 mg/day) and calcium (5–117 g/day at 6–12 months, 210–330 g/day at 12–24 months) are also needed.

4. Grain products, legumes, fruits, and vegetables should also be included in the diet. If milk and other animal-source foods are not consumed in adequate amounts, both grains and legumes should be consumed daily, if possible within the same meal, to ensure adequate protein quality. In general, one or two types of fruit and one to three types of vegetables per day can be recommended. The amounts included in the LP analyses can be found in tables 4 to 12. These are meant to be examples of the types and amounts of foods to include, not explicit dietary guidelines. Such guidelines need to be created at the local level, based on the types of foods available in the area and at different seasons of the year.

5. If fortified products such as Nutributter, Sprinkles, Foodlets, or CSB are available, there is no need for commercial infant formula, and nonmilk animal-source foods are optional. With adequate levels of micronutrients in the product, there is also no need for additional supplements. If milk is included in the diet, the amount needed is generally less than when fortified products are not included. If milk is not included in the diet, calcium needs may not be completely met (because some of the products contain little or no calcium), and the product would need to contain vitamin B_{12} if there are no other animal-source foods in the diet. Fortified products allow for a simpler and presumably more affordable diet, depending on local food composition and costs.

6. Cost comparisons of three different complementary food supplements (Nutributter, Foodlets, and Sprinkles) and CSB indicate that at 6 to 12 months, the Nutributter or CSB options resulted in lower-cost diets in some situations, but otherwise the costs were similar. At 12 to 24 months, the CSB option was least

expensive. Because it is difficult to incorporate all of the essential micronutrients into Foodlets or Sprinkles, the diets using those options sometimes required a wider variety or larger quantities of fruits and vegetables than the diets based on the Nutributter or CSB options. Nonetheless, the choice of which type of product to use will depend on local circumstances. There is limited experience with the use of complementary food supplements in community settings, but preliminary evidence indicates that they are acceptable to mothers and infants.

7. If animal-source foods are not consumed regularly, 10 to 20 g of added fats or oils are needed unless a fat-rich food is given (such as foods or pastes made from groundnuts, other nuts, and seeds). If animal-source foods are consumed, up to 5 g of additional fats or oils may be needed in some circumstances. Good sources of essential fatty acids (e.g., fish, avocado, nut pastes, and most vegetable oils) should be included.

8. Nonbreastfed infants need at least 400 to 600 ml/day of water (in addition to water contained in foods, including milk) in a temperate climate, and 800 to 1200 ml/day in a hot climate. This water can be incorporated into porridges or other foods, but plain, clean (boiled, if necessary) water is less prone to contamination and should be offered several times per day to ensure that the infant's thirst is satisfied.

9. The number of meals required by nonbreastfed children depends on the energy density of the local foods and the usual amounts consumed at each feed. When the energy density is at least 0.8 kcal/g and children are fed to satiety, four or five meals per day are needed (meals include milk-only feeds, other foods, and combinations of milk feeds and other foods). If the energy density or the amount of food per meal is low, more frequent meals may be required. In all situations, responsive feeding practices that are sensitive to the child's hunger and satiety cues are advisable [3].

It is important to keep in mind that there are several limitations to the LP analyses described here.

First, the analyses are based on meeting the needs for selected nutrients (energy, fat, protein, vitamin A, thiamine, riboflavin, vitamin B_6, folate, vitamin C, calcium, iron, and zinc), not for all of the essential nutrients. Although these are the nutrients considered to be most limiting at this age, the results could be different if other micronutrients were included, such as vitamin E, iodine, phosphorus, selenium, or essential fatty acids. Unfortunately, there is inadequate or unreliable information on the content of these nutrients in many foods, precluding their inclusion in the LP analyses.

Second, there is still uncertainty about the RNI values during infancy, as explained in section 3.2.4, so the results could differ if better estimates were available.

Third, the food-composition data used are subject to error, and there is considerable variability in nutrient content due to local conditions, such as soil, cultivar, processing, etc.

Fourth, although the LP analyses take the bioavailability of iron, zinc, and calcium into account, the calculations are based on the entire day's diet, not the bioavailability of the food in each individual meal. This introduces some unavoidable error into the results.

Fifth, the maximum amounts of individual foods allowed in these analyses were based on a limited number of dietary studies, mostly of breastfed infants under 12 months of age. There was little information on the quantities that could be consumed in the second year of life. As a result, the solutions for children from 12 to 24 months may have been overly constrained by the limitations imposed on food quantity.

Finally, the food cost estimates used in specific LP analyses could be incorrect, and will certainly vary by region and across time. Use of different food costs can greatly alter the types and amounts of foods that appear in the LP solutions.

Several of the above limitations can be overcome by running the LP analyses using locally available data specific to the region of interest. It is important to note that tables 4 to 12 in this report are intended to be an overall guide, not recommendations to be applied to all settings. If local food composition and cost information is available, local authorities can conduct their own assessment of dietary needs for nonbreastfed children in their area. This may yield solutions that differ somewhat from those shown in this report. For example, dietary data from a research study of 242 children 6 to 23 months of age in Malawi (representing 320 dietary records) were obtained [37] (Dr. Christine Hotz, personal communication) and run through the same LP analyses as described here. The resulting solutions were similar to those for Ghana, but because the maximum amounts of certain foods consumed were greater in Malawi than in Ghana (e.g., green leafy vegetables, beans, and pumpkin), the diets included more of these foods and fewer animal-source foods (though iron supplements were still needed). Once a local assessment is completed using LP, further work is needed to develop recipes and dietary guidelines that can be used by caregivers. This will need to include careful attention to the amount of fluid needed in the overall diet, as explained in section 3.6.

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Conclusions of an informal meeting on infant and young child feeding organized by the World Health Organization, Geneva, March 8–10, 2004

Informal Working Group on Feeding of Nonbreastfed Children

According to current United Nations recommendations, infants should be exclusively breastfed for the first six months of life and thereafter should receive appropriate complementary feeding with continued breastfeeding up to two years or beyond. However, there are a number of infants who will not enjoy the benefits of breastfeeding in the early months of life or for whom breastfeeding will stop before the recommended period of two years or beyond. A group that calls for particular attention consists of the infants of mothers who are known to be HIV positive. To reduce the risk of HIV transmission, it is recommended that when it is acceptable, feasible, affordable, sustainable, and safe, these mothers give replacement feeding from birth. Otherwise, they should breastfeed exclusively and stop as soon as alternative feeding options become feasible. Another group includes those infants whose mothers have died, or who for some reason do not breastfeed.

Recommendations for appropriate feeding of breastfed infants from six months onwards have been summarized by the Pan American Health Organization (PAHO) in the publication *Guiding Principles for Complementary Feeding of the Breastfed Child* [1]. Some of these Guiding Principles are not applicable to nonbreastfed children, whereas others need adaptation. The World Health Organization (WHO) convened this informal meeting to identify an analogous set of guiding principles for feeding nonbreastfed children after six months of age.

The outline of the adapted Guiding Principles is presented in Box 1. These guidelines were developed on the basis of the evidence presented in the background document published in this issue of the *Food and Nutrition Bulletin* [2] and developed based on consensus by participants in the meeting [3].

Beyond the development of these Guiding Principles, the following points were discussed:

Duration of exclusive breastfeeding in the context of HIV

A previous meeting examined the issue of infant feeding in the context of HIV/AIDS and concluded that when breastmilk substitutes were not acceptable, feasible, affordable, sustainable, and safe, then exclusive breastfeeding (breastmilk only, with no other food or drink except vitamin and mineral drops, not even water) should be recommended for the first few months [4]. In the present meeting, it was also acknowledged that the precise timing of breastfeeding cessation should be determined after examining the risks attached to early cessation and continuation of breastfeeding. It was confirmed that the optimal time of breastfeeding cessation varies according to individual circumstances. Attention was drawn to the risk of recommending complete early cessation of breastfeeding for mothers with no safe option for infant feeding after that time.

Expressing and heat-treating breastmilk to reduce the risk of HIV transmission

Boiling breastmilk may damage some of its nutrients and does not seem an acceptable option. An adapted method of breastmilk pasteurization developed in Pretoria seems more suitable: boiling a pan of water, removing it from the heat source, and immediately placing a covered glass jar of breastmilk in the water for 20 minutes was shown in two studies to eliminate HIV [5, 6]. Heating a pan of water with a jar of breastmilk in it until the water begins to boil, and then immediately removing the jar from the water, eliminated the virus in another study [7]. The safety of these approaches

The members of the Informal Working Group are listed at the end of the text of this article. Please direct queries to: Dr André Briend (brienda@who.int) or Dr. Peggy Henderson (hendersonp@who.int) at the World Health Organization Department of Child and Adolescent Health and Development, Geneva.

BOX 1. Summary of Guiding Principles for feeding nonbreastfed children 6 to 24 months of age

1. Amount of Food Needed
Guideline: Ensure that energy needs are met. These needs are approximately 600 kcal/day at 6–8 months of age, 700 kcal/day at 9–11 months of age, and 900 kcal/day at 12–23 months of age.

2. Food Consistency
Guideline: Gradually increase food consistency and variety as the infant gets older, adapting to the infant's requirements and abilities. Infants can eat puréed, mashed, and semisolid foods beginning at 6 months. By 8 months most infants can also eat "finger foods" (snacks that children can eat on their own). By 12 months, most children can eat the same types of foods as consumed by the rest of the family (keeping in mind the need for nutrient-dense foods; see #4 below). Avoid foods in a form that may cause choking (i.e., items that have a shape and/or consistency that may cause them to become lodged in the trachea, such as nuts, grapes, raw carrots). Such foods should be mashed, puréed, or juiced before being fed to young children.

3. Meal Frequency and Energy Density
Guideline: For the average healthy infant, meals should be provided 4–5 times per day, with additional nutritious snacks (such as pieces of fruit or bread or chapatti with nut paste) offered 1–2 times per day, as desired. The appropriate number of feedings depends on the energy density of the local foods and the usual amounts consumed at each feeding. If energy density or amount of food per meal is low, more frequent meals may be required.

4. Nutrient Content of Foods
Guideline: Feed a variety of foods to ensure that nutrient needs are met.

» Meat, poultry, fish, or eggs should be eaten daily, or as often as possible, because they are rich sources of many key nutrients such as iron and zinc. Milk products are rich sources of calcium and several other nutrients. Diets that do not contain animal-source foods (meat, poultry, fish, or eggs, plus milk products) cannot meet all nutrient needs at this age unless fortified products or nutrient supplements are used.

» If adequate amounts of other animal-source foods are consumed regularly, the amount of milk needed is ~200–400 ml/d; otherwise, the amount of milk needed is ~300–500 ml/d. Acceptable milk sources include full-cream animal milk (cow, goat, buffalo, sheep, camel), ultra-high temperature (UHT) milk, reconstituted evaporated (but not condensed) milk, fermented milk or yogurt, and expressed breast milk (heat-treated if HIV-positive).

» If milk and other animal-source foods are not eaten in adequate amounts, both grains and legumes should be consumed daily, within the same meal if possible, to ensure adequate protein quality.

» Dairy products are the richest sources of calcium. If dairy products are not consumed in adequate amounts, other foods that contain relatively large amounts of calcium, such as small fish that include the bones (dried or fresh, with the bones crushed or otherwise processed so that they are safe to eat) and lime-treated maize tortillas, can fill the gap. Other foods such as soybeans, cabbage, carrots, squash, papaya, green leafy vegetables, guava, and pumpkin are useful additional sources of calcium.

» The daily diet should include vitamin A-rich foods (e.g., dark-colored fruits and vegetables, red palm oil, vitamin A fortified oil or foods); vitamin C rich foods (e.g., many fruits, vegetables, and potatoes) consumed with meals to enhance iron absorption; and foods rich in the B vitamins, including riboflavin (e.g., liver, egg, dairy products, green leafy vegetables, soybeans); vitamin B6 (e.g., meat, poultry, fish, banana, green leafy vegetables, potato and other tubers, peanuts); and folate (e.g., legumes, green leafy vegetables, orange juice).

» Provide diets with adequate fat content. If animal-source foods are not consumed regularly, 10–20 g of added fats or oils are needed unless a fat-rich food is given (such as foods or pastes made from groundnuts,

continued

needs further evaluation. Their acceptability remains an open question.

Use of plain cow's milk for feeding nonbreastfed children

The use of plain cow's milk raises some concerns because of the low content and bioavailability of iron in cow's milk, possible occult gastrointestinal blood loss, and high potential renal solute load. These concerns should not prevent the use of cow's milk after the age of six months. Iron deficiency can be prevented by adequate supplementation. Occult blood loss decreases with age and usually disappears by the age of 12 months. Heat-treated cow's milk does not provoke blood loss. The potential renal solute load of cow's milk is indeed higher than that of breastmilk but this does not seem to be a problem in children more than six months of age, who have a more mature kidney function, provided the child is regularly offered plain water [2].

Support for replacement feeding after six months

In resource-poor settings, families may require extra support to appropriately feed infants after early cessation of breastfeeding. Several alternative ways of achieving this were discussed in the meeting. The World Food Program is developing a strategy to integrate food aid with programs for Prevention of

BOX 1. Summary of Guiding Principles for feeding nonbreastfed children 6 to 24 months of age *(continued)*

other nuts, and seeds). If animal-source foods are consumed, up to 5 g of additional fats or oils may be needed.

» Avoid giving drinks with low nutrient value, such as tea, coffee, and sugary soft drinks. Limit the amount of juice offered, to avoid displacing more nutrient-rich foods.

5. Use of Vitamin-Mineral Supplements or Fortified Products
Guideline: As needed, use fortified complementary foods or vitamin-mineral supplements (preferably mixed with or fed with food) that contain iron (8–10 mg/day at 6–12 months, 5–7 mg/day at 12–24 months). If adequate amounts of animal-source foods are not consumed, these fortified foods or supplements should also contain other micronutrients, particularly zinc, calcium, and vitamin B12. In countries where vitamin A deficiency is prevalent or where the under-five mortality rate is more than 50 per 1000, it is recommended that children 6–24 months old receive a high-dose vitamin A supplement (100,000 IU once for infants 6–12 months old and 200,000 IU biannually for young children 12–23 months old).

6. Fluid Needs
Guideline: Nonbreastfed infants need at least 400–600 ml/day of extra fluids (in addition to the 200–700 ml/day of water estimated to come from milk and other foods) in a temperate climate, and 800–1200 ml/day in a hot climate. Plain, clean (boiled, if necessary) water should be offered several times per day to ensure that the infant's thirst is satisfied.

7. Safe Preparation and Storage of Foods
Guideline: Practice good hygiene and proper food handling by a) washing caregivers' and children's hands with soap before food preparation and eating, b) storing foods safely and serving foods immediately after preparation, c) using clean utensils to prepare and serve food, d) using clean cups and bowls when feeding children, and e) avoiding the use of feeding bottles, which are difficult to keep clean (for additional details, see WHO Complementary Feeding: Family foods for breastfed children, 2000 and Five Keys to Safer Food http://www.who.int/foodsafety/publications/consumer/5keys/en/).

8. Responsive Feeding
Guideline: Practice responsive feeding, applying the principles of psychosocial care. Specifically, feed infants directly and assist older children when they feed themselves, being sensitive to their hunger and satiety cues; feed slowly and patiently, and encourage children to eat, but do not force them; if children refuse many foods, experiment with different food combinations, tastes, textures, and methods of encouragement; minimize distractions during meals if the child loses interest easily; and remember that feeding times are periods of learning and love — talk to children during feeding, with eye-to-eye contact.

9. Feeding During and After Illness
Guideline: Increase fluid intake during illness and encourage the child to eat soft, varied, appetizing, favorite foods. After illness, give food more often than usual and encourage the child to eat more.

Mother-to-Child Transmission (PMTCT) of HIV, and hence could target infants and young children of HIV-positive mothers with supplementary foods such as corn-soya blend or an equivalent alternative after the cessation of breastfeeding. These fortified foods were not initially designed for replacement feeding but may be useful additional sources of micronutrients to supplement the diet of nonbreastfed children. The Food and Agriculture Organization (FAO) is supporting an approach that involves strengthening of livelihoods and food security for individuals and households infected and affected by HIV/AIDS. Linkage of these efforts with PMTCT programs offers the potential for providing support to increased household food production at an early stage, during pregnancy and in the postpartum period. As an alternative option, the participants discussed the provision of free formula as a supplement to the local diet after early cessation of breastfeeding. Substantial experience has been gained in this field by UNICEF and some governments that supported the provision of free formula to HIV-positive women starting from birth as part of PMTCT programs. There are obvious health risks associated with formula feeding if the formula is not prepared and given safely, as well as the potential of spillover to the general population. The participants agreed that if free formula were to be considered, mothers should be guided by skilled counselors. Free distribution should also comply with the provisions laid down in the International Code of Marketing of Breast-Milk Substitutes and subsequent World Health Assembly resolutions [8].

Next steps

The Guiding Principles for feeding nonbreastfed children 6 to 24 months of age, together with their rationale, will be presented in an official WHO document currently under preparation. For further details, kindly consult the following websites: http://www.who.int/child-adolescent-health/ and http://www.who.int/nut. Accessed September 12, 2004.

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