Insights from Optifood modeling to support revision of infant and young child feeding recommendations: Full report

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June 2022

Acknowledgments

The authors are very grateful to many individuals who generously provided advice, discussion, assistance, and/or data at various stages of the work. We thank:

- Lawrence Grummer-Strawn and Lisa Rogers of WHO, and Chessa Lutter (consultant to WHO), for guidance and advice throughout the project.
- Members of the WHO Guideline Development Group on Guidelines for Feeding Infants and Young Children 6-23 Months of Age, subgroup on modeling, for their guidance and advice: Richmond Aryeetey, Kathryn Dewey, Lora Iannotti, Rafael Pérez-Escamilla, Inês Rugani Ribeiro de Castro, Zhenyu Yang. Kathryn Dewey also provided initial estimates of energy requirements and information on amino acid content of lipid-based nutrient supplements.
- Seth Adu-Afarwuah, for input on selection of nutrient reference values.
- Jason Montez (WHO) and Magali Rios-Leyvraz for sharing drafts of a systematic review of breast milk intake, for providing analysis and tables for age-disaggregated estimates of breast milk volume consumed, and for discussions of these results.
- TusaRebecca Pannucci for providing food composition data for the representative food item list used in national US food pattern modeling for children under two, and for discussions about methodological details in the US approach.
- Gilberto Kac, Inês Rugani, Elisa Lacerda and Letícia Vertulli, for analyzing national data from Brazil and providing us with tables.
- Alissa Pries, for analyzing Assessment and Research on Child Feeding (ARCH) Project data and providing us with tables.
- Hilary Creed-Kanashiro and Lizette Ganoza (Instituto de Investigación Nutricional) for providing unpublished data from a project in Peru, and for information on specific local food items.
- Sonia Rodríguez Ramírez, María Concepción Medina Zacarías, Andrys Valdez Sánchez, Teresa Shamah Levy, and Anna Herforth for providing processed dietary data from Mexico, with food group coding and replacements for fortified items.
- Lora Ianotti, Chessa Lutter, Kenneth Maleta, and Christine Stewart for authorizing use of Mazira study data, Bess Caswell, Charles Arnold, and Christine Stewart for discussions the data, and Charles Arnold for providing a consolidated data set.
- Jaimie Hemsworth-Hummelen and Lotta Hallamaa for sharing iLiNS-DOSE study data and Jaimie Hemsworth-Hummelen for discussions of the data and for providing an unpublished compiled food composition database.
- Wahid Quabili, for discussions of data from Bangladesh and for sharing additional processed data files and documentation.
- Joanne Arsenault, for discussions of processing of US dietary data, and for sharing processed data.
- Frances Knight, for providing tables of Optifood inputs from a study in Guatemala.
- Zhiyong Zou for sharing processed data from the 2011 China Health and Nutrition Survey (CHNS).

- Helena Pachon, for sharing unpublished reports from Process for the Promotion of Child Feeding (ProPAN) studies.
- Umi Fahmida, Sengchanh Kounnavong, Bach Mai Le, and Pattanee Winichagoon, for sharing unpublished reports from the SMILING Project.
- Kendra Byrd, Shakuntala Thilsted, and Ty Beal for sharing ideas and resources on food composition data sources for specific nutrient-dense foods.
- Henrietta Ene-Obong, for providing an electronic version of the Nigerian food composition table.
- Kirsten Herrick, for discussions of US dietary data.
- Rebecca Robert, for discussions of Enhancing Nutrition Services to Improve Maternal and Child Health in Africa and Asia (ENRICH) Project reports and data.
- Veronica Luque, for discussions of the European Childhood Obesity Project (CHOP) study
- Lital Keinan-Boker, Rebecca Goldsmith, Tal Shimony and Lesley Nitsan for discussions of Israeli data.
- Grace Marquis, Beatrice Ekesa, and Paul Eme for sharing data sets or tables.
- Zaid Chalabi and Kenneth Simler for statistical advice.
- Andrew Simler for assistance collating information and formatting tables and figures.

Acroynms

AI	Adequate intake
AMDR	Acceptable Macronutrient Distribution Range
ARCH	Assessment and Research on Child Feeding
ASEAN	Association of Southeast Asian Nations
CHOP	European Childhood Obesity Project
DGAC	Dietary Guidelines Advisory Committee
DRI	Dietary reference intake
DRV	Dietary reference value
EER	Estimated energy requirement
EFSA	European Food Safety Authority
ENANI	Brazilian National Survey on Child Nutrition
ENRICH	Enhancing Nutrition Services to Improve Maternal and Child Health in Africa and Asia
FNDDS	Food and Nutrient Database for Dietary Studies
GIFT	Global Individual Food Consumption data Tool
GDG	WHO Guideline Development Group on Guidelines for Feeding Infants and Young Children 6-23 Months of Age
IIN	Instituto de Investigación Nutricional
INFOODS	International Network of Food Data Systems
IYC	Infants and young children
IYCF	Infant and young child feeding
MNP	Multiple micronutrient powder
NASEM	National Academies of Sciences, Engineering, and Medicine
NRV	Nutrient reference value
PRI	Population Reference Intake
ProPAN	Process for the Promotion of Child Feeding
RDA	Recommended Dietary Allowance
RI	Reference Intake range
SMILING	Sustainable Micronutrient Interventions to Control Deficiencies and Improve Nutritional Status and General Health in Asia
SQ-LNS	Small-quantity lipid-based nutrient supplement
SSB	Sugar-sweetened beverage
UL	Tolerable Upper Intake Level

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1. Introduction and overview of modeling questions

The WHO Guideline Development Group on Guidelines for Feeding Infants and Young Children 6-23 Months of Age (hereafter, GDG) identified certain topics that would benefit from application of diet or food pattern modeling approaches to complement information from commissioned systematic and narrative reviews. This report summarizes the results of modeling exercises designed to inform feeding recommendations. The modeling exercises were designed to explore impacts of various modifications in infant and young child food patterns on the nutrient content of the diet relative to selected nutrient reference values (NRVs).[1]

The GDG selected the Optifood modeling system for this exercise. Optifood was originally developed by WHO in collaboration with other experts (Daelmans et al. 2013). In one module, Optifood employs a type of multi-objective optimization, 'goal programming'. This means that multiple objectives – for example, meeting multiple nutrient requirements – can be modeled simultaneously, with the 'solution' being the set of results (food group and subgroup quantities per week) that minimizes the sum of all gaps, where nutrient values fall below the NRVs.

Models are specified based on an objective (that is, simultaneously minimizing multiple nutrient gaps) and on a set of constraints (or parameters). In this application, constraints include energy intakes (equality constraint), and minimum and maximum allowed quantities and frequencies of consumption, for a set of defined food groups and subgroups.

After selecting Optifood as the preferred modeling application, the GDG and WHO further defined the questions to be addressed in modeling. Optifood has typically been used to generate food-based recommendations defined by the numbers of servings of food groups, subgroups or individual foods to consume to meet nutrient needs (Ferguson et al. 2006; Daelmans et al. 2013). In this context, it was used differently. Specifically, the Optifood system was used to address the following questions:

1. Can target nutrient needs be met with unfortified best-case food patterns? If so, what do these food patterns look like?
2. What happens when food groups or subgroups are eliminated?
3. What happens when staple foods are monotonous?
4. What happens if we modify the amount of starchy staple foods?
5. What happens if we add unhealthy foods or beverages?
6. What happens if we add fortified foods or products?
7. What are the nutrient gaps when we approximate real-world food patterns, and can they be filled by use of fortified products?

The starting point for questions two through six were best-case food patterns derived from the first stage of Optifood modeling (question one). The best-case food patterns were developed based on allowing generous but feasible quantities of a range of nutrient-dense food subgroups. Development of this 'feasible best-case food pattern' is described in detail below.

The last question was approached differently, and through calculations rather than by modeling. Food patterns were developed based on the approximate percent of energy from food groups observed in

[1] The term 'nutrient Reference value' sometimes refers specifically to values used for food labeling, but sometimes is used as a generic term for various types of reference values. We use it in this latter sense; see, for example, https://www.nrv.gov.au/introduction.

several low- and middle-income country settings, and the nutrient gaps implied by these patterns were assessed.

We note that our scope was defined by the questions above. Considerable additional work would be required to develop food-based recommendations for any given setting.

2. Methods

The following sections detail:

a. Basic parameters for modeling
b. Other modeling inputs and parameters
c. Modeled scenarios and descriptive analysis

2a. Basic parameters for modeling

Parameters described in this section could be developed without analysis of data sets. Many relied on input from the GDG and/or on review of other modeling exercises. Parameters described in this section are:

- Age groups, energy intake levels, and feeding groups for modeling
- Estimated energy from breast milk and energy constraints for modeling
- Nutrient reference values
- Nutrient content of breast milk and nutrient targets for modeling
- Food groups and subgroups for modeling

2a.1. Age groups, energy intake levels, and feeding groups for modeling

Decisions on groups for modeling were taken in consultation with the GDG and WHO staff.

- Age groups and energy intake levels (see **Annex 1** for justification of selection of energy levels):
    - 6-8.9 months: 518, 643 and 776 kilocalories
    - 9-11.9 months: 598, 723 and 848 kilocalories
    - 12-23.9 months: 650, 863 and 1086 kilocalories

Note that while we modeled separately for 6-8.9 month and 9-11.9 month age groups, NRVs (below) are the same across these two groups.

- Milk feeding:
    - For 6-8.9 and 9-11.9 months, model breastfed infants only
    - For 12-23.9 months, model breastfed and non-breastfed children separately

Table 1. Summary table of twelve groups for modeling

	Energy level (kilocalories)[a]		
Age and milk feeding	**Low**	**Middle**	**High**
6-8.9 mo			
Breastfed	518	643	776
9-11.9 mo			
Breastfed	598	723	848
12-23.9 mo			
Breastfed	650	863	1086
Non-breastfed	650	863	1086

[a] See Annex 1 for calculations of estimated energy requirements (EERs). Low energy levels are the EER of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

2a.2. Estimated energy from breast milk and energy constraints for modeling

Estimates for breast milk volume (milliliters per kilogram per day) were provided by the authors of a recent systematic review.[2] We used values for the 'best' studies, rather than all studies in the review. Best studies were defined as those with healthy mothers and healthy term infants exclusively breastfed up to six months.

Mean values for each age group are shown in **Table 2**, for the median size child in each age group. Values for smaller and larger children were back-calculated as follows: First, for the median-sized child in each age group, we calculated the percent of energy from breast milk, in the following steps:

1. We converted mean breast milk volume to weight using the conversion factor of 1.04 g/mL to determine grams of breast milk;[3]
2. We converted grams of breast milk to kilocalories based on the energy density of breast milk, using a value of 0.65 kilocalorie/gram;[4] and
3. We calculated the percent of the estimated energy requirement met by breast milk, for the median-sized child.

We then applied this same percentage for the smaller and larger children in each age group, and back-calculated the implied milliliters per kilogram per day for these children; this approach resulted in a consistent percent of energy from breast milk within each age group, across body sizes.

The estimated energy requirements (EERs) in Table 2 were the energy constraints (an equality constraint) in the models for each given age/body weight/feeding group combination. For each of the twelve scenarios, grams of breast milk (and thus energy intake from breast milk) were fixed at the indicated levels. Table 2 also shows the remaining kilocalories available for complementary foods and other beverages ('Non-BM kcal/d').

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[2] Confidential draft report: (Yao and Rios-Leyvraz 26 Aug 2021) and additional results provided by Dr. Magali Rios-Leyvraz (personal communication, 4 October 2021). The additional results provided further disaggregation by age (6-8.9 and 9-11.9 months), compared to results in the draft report (which gave estimates across 6-11.9 months).

[3] To identify a volume-to-weight conversion, we first searched the global FAO International Network of Food Data Systems (INFOODS) conversion factor database (version 2.0) but there is no conversion value for human milk. The US Food and Nutrient Database for Dietary Studies (FNDDS) 2017-2018 gives a conversion for human milk (g/fluid oz), which was further converted to g/ml. The US conversion factor database 'Portions and weights.xlsx' is available at: https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/fndds-download-databases/, accessed 5 May 2021.

[4] Determining energy density of breast milk is difficult due to diurnal, within feed, and between breast changes in fat content. For the purposes of this exercise, we used the value used by the US food pattern modeling team (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020).

Table 2. Estimated energy from breast milk and other foods and beverages for different size children in three age groups[a, b]

	Kg	EER	mL BM per kg/d[c]	BM kcal per d	BM g per d	Non-BM kcal per d	% energy from BM
6-8.9 mo							
Low	6.7	518	88	399	611	119	77%
Middle	8.1	643	90	496	758	147	77%
High	9.6	776	92	598	915	178	77%
9-11.9 mo							
Low	7.6	598	73	380	581	218	63%
Middle	9.0	723	75	459	702	264	63%
High	10.4	848	76	538	823	310	63%
12-23.9 mo, BF							
Low	8.2	650	52	288	440	362	44%
Middle	10.6	863	53	382	584	481	44%
High	13.1	1086	54	481	735	605	44%
12-23.9 mo, non-BF							
Low	8.2	650	0	0	0	650	0%
Middle	10.6	863	0	0	0	863	0%
High	13.1	1086	0	0	0	1086	0%

[a] BF = breastfed; BM = breast milk; EER = estimated energy requirement.

[b] See Annex 1 for calculations of estimated energy requirements (EER). Low energy levels are the EER of girls at the low end of each age range and the 25th percentile for weight-for-age. Medians are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] Values for mL breast milk per kg per day, personal communication from Dr. Magali Rios-Leyvraz, 4 October 2021.

2a.3. Nutrient reference values

2a.3.1. List of nutrients

Based on decisions by the GDG subgroup on modeling, the list of target nutrients for modeling includes the set of nutrients that are built into the Optifood modeling system, with the exceptions of carbohydrate, protein, and niacin, and with the additions of choline and potassium (**Table 3**).[5] Nutrients in the Optifood modeling system were originally selected by WHO and collaborating experts based on public health significance and availability of nutrient composition data across settings (E. Ferguson, personal communication).

Modeling results are also reported for other selected nutrients that were not built into models as targets (Table 3). In addition to reporting macronutrients as percent of NRVs, we report as percent of

[5] Due to limitations in the number of nutrients Optifood can model simultaneously, inclusion of new nutrients required dropping of other Optifood nutrients. The GDG considered choline and potassium to be of high importance and requested inclusion of these as target nutrients. Protein was considered to be of less urgent interest, since there is evidence that protein intakes and protein quality may be adequate even in low-income settings, so long as energy intakes are adequate (Arsenault and Brown 2017). Niacin was viewed as less informative than niacin equivalents, and at the time these decisions were taken we were unsure whether complete data on amino acids would be available for all food items, to allow calculation of niacin equivalents.

energy, in relation to reference ranges (see below). In addition to the target nutrients in Table 3, energy was entered into all models as a fixed constraint, at the levels described above.

Table 3. List of target nutrients and other nutrients for reporting

Target nutrients	Other nutrients
Fat	Protein
Vitamin A	Carbohydrate
Thiamin	Linoleic Acid (LA)
Riboflavin	α-linolenic acid (ALA)
Vitamin B-6	Fiber
Folate	Niacin
Choline	Vitamin D
Vitamin B-12	Copper
Vitamin C	Magnesium
Calcium	Phosphorus
Iron	
Potassium	
Zinc	

While energy was fixed, target nutrients are included in the objective (which minimizes the sum of their deviations below desired values) but are not model constraints. That is, the nutrient content of the model solutions can fall short of or exceed the desired values. Desired values for each target nutrient were defined based on NRVs.

2a.3.2. Sources for Nutrient Reference Values

Sources for NRVs were:

1. The dietary reference intakes (DRIs) of the US and Canada (National Academies of Sciences, Engineering, and Medicine (NASEM) 2019); and
2. The dietary reference values (DRVs) of the European Food Safety Authority (EFSA 2017).

The NASEM DRIs include Recommended Dietary Allowances (RDAs), Adequate Intakes (AIs) and Acceptable Macronutrient Distribution Ranges (AMDR); the EFSA DRVs include Population Reference Intakes (PRIs), AIs, and Reference Intake ranges (RIs).

Annex 2 provides a comparison of the two sets of NRVs and details on our selection criteria for NRVs. In brief, we preferred RDAs or PRIs to AIs, and preferred more recent over less recent NRVs. **Table 4** shows the selected NRVs for each target nutrient.

Annex 2 also includes a table showing NRVs for non-target nutrients, and a table with values for Tolerable Upper Intake Levels (ULs). ULs were not used as constraints in models; that is, model solutions could exceed ULs. However, all results were reviewed against ULs, and any instances where ULs were exceeded are noted and reported with results, below.

Table 4. Nutrient reference values for target nutrients for modeling[a]

Target nutrients	6-11.9 mo	Notes	12-23.9 mo	Notes
Fat (% energy)	40	AI	35[b]	RI
Vitamin A (µg RE/d)	250	PRI	250	PRI
Thiamin (mg/d)	0.3	AI	0.5	RDA
Riboflavin (mg/d)	0.4	AI	0.6	PRI
Vitamin B6 (mg/d)	0.3	AI	0.6	PRI
Folate (µg DFE/d)	80	AI	120	PRI
Choline (mg/d)	160	AI	140	AI
Vitamin B12 (µg/d)	0.5	AI	0.9	RDA
Vitamin C (mg/d)	20	PRI	20	PRI
Calcium (mg/d)	280	AI	450	PRI
Iron (mg/d)	11	PRI	7	PRI
Potassium (mg/d)	750	AI	800	AI
Zinc (mg/d)	2.9	PRI	4.3	PRI

[a] Values are from the US/Canadian Dietary Reference Intakes (DRIs) (National Academies of Sciences, Engineering, and Medicine 2019) and the European Food Safety Authority (EFSA) Dietary Reference Values (DRVs) (EFSA 2017). AI = Adequate Intake; PRI = Population Reference Intake; RDA = Recommended Dietary Allowance; RI = Reference Intake range.

[b] 35% is the low end of the EFSA Reference Intake range for fat as a percent of energy for 1-3 year olds. A single value was needed for the target, and in consultation with the GDG we chose the low end of the range.

In addition to modeling using the nutrient targets in Table 4, we also performed sensitivity analyses for lower iron absorption (5%) than is assumed in the NRVs in Table 4 (10%).[6] See Annex 2 for further details on NRVs and absorption.

2a.4. Nutrient content of breast milk and nutrient targets for modeling

We used the values for nutrient content of breast milk employed in the US food pattern modeling exercise for infants and young children under two years of age (2020 Dietary Guidelines Advisory Committee (DGAC) and Food Pattern Modeling Team 2020, (Table 4.2 pp 35-36)). Nutrient content is given per liter of human milk.

Table 5 shows the nutrient content of breast milk both for target nutrients and other reported nutrients. The footnotes to the table are adapted from the DGAC table. In addition to the values in Table 5, a value for tryptophan was imputed, to allow calculation of niacin equivalents.[7]

[6] These sensitivity analyses were added to the original plan, and only for best-case scenarios that resulted in no iron gap yet had low animal-source protein food intake.

[7] The value for tryptophan was imputed from the US Food Data Central website value, food code SR 1107 (https://fdc.nal.usda.gov/fdc-app.html#/food-details/171279/nutrients), accessed March 21, 2022.

Table 5. Nutrient content of human milk[a, b]

Component	Amount per liter	Component	Amount per liter	Component	Amount per liter
Calories, kcal	680	Vitamin A, µg_RAE	485	Calcium, mg	200
Protein, g	12.1	Thiamin, mg	0.2	Copper, mg	0.2
Carbohydrate, g	74	Riboflavin, mg	0.4	Iron, mg	0
Fiber, total dietary, g	0	Niacin, mg	1.8	Magnesium, mg	34
Total lipid (fat), g	38	Vitamin B-6, mg	0.1	Phosphorus, mg	124
18:2 Linoleic acid, g	5.6	Vitamin B-12, µg	0.4	Potassium, mg	435
18:3 Linolenic acid, g	0.6	Choline, mg	160	Zinc, mg	0.8
		Folate, mcg DFE	85		
		Vitamin C, mg	45		
		Vitamin D, IU	0		

[a] Values for 1 liter of breast milk are from 2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team (2020), Table 4.2 pp 35-36. Note that these values are for milk composition at > 6 months postpartum.

[b] Nutrient amounts are the mean concentrations of each nutrient published in the respective reports for the development of the US/Canadian Dietary Reference Intakes for infants (see below) with the exceptions of energy, total fat and iron. For energy, the value of 680 kcal/L was based on compiled evidence on the metabolizable energy of human milk (Reilly, Ashworth, and Wells 2005). For total fat, the mean of mean values from the DRI report for older infants (ages 6 to 12 months) of 38 g/L was used (Institute of Medicine 2005a). Contribution of iron from human milk after age 6 months was rounded down to 0.

Citations for the reports: (Institute of Medicine 1997; 1998; 2000; 2001; 2005a; 2005b; 2011; National Academies of Sciences, Engineering, and Medicine 2019).

Human breast milk was entered as an item in the Optifood model food list with its associated food composition data, and with quantities in grams as defined in Table 2. Nutrient targets for modeling for non-breastfed children 12-23.9 months of age were the selected NRVs (Table 4). For breastfed infants in all age groups, because the quantity of breastmilk modelled was fixed, nutrient targets from complementary foods were equivalent to the selected NRVs minus the amount of nutrients assumed to be provided by breast milk.

2a.5. Food groups and subgroups for modeling

2a.5.1. Uses of food groups and subgroups

Food groups and subgroups were employed in several ways. Nutrient profiles were developed at the food subgroup level, and we modeled at this level (rather than at the level of individual food items).[8] Quantitative parameters were also developed at the food subgroup level, as well as at the food group level.

These parameters (quantity and frequency of consumption) yielded maximum values in grams per week of consumption (details below). Based on the nutrient profiles, the Optifood model selected a given amount of the various food subgroups and groups, up to the maximum amount allowed, with the objective of meeting target nutrient needs.

[8] We modeled at the food subgroup level rather than the item level because individual food items vary too widely across geographic settings, while the food subgroups were consumed by infants and young children (IYC) in most settings.

2a.5.2. Broad food groups

We used the following broad food groups:

1. Starchy staple foods (grains plus white roots and tubers, and plantains)
2. Fruits
3. Vegetables
4. Dairy
5. All other protein foods (meat, poultry, fish, eggs, nuts and seeds, legumes, soy foods)
6. Added fats and oils

Excluding added fats and oils, the first five comprise the most common five food group set in national food-based dietary guidelines, globally (Herforth et al. 2019).

2a.5.3. Selection of food subgroups

Because they were used to develop nutrient profiles, food subgroups needed to be well-selected and sufficiently narrow such that nutrient profiles differed in a meaningful way between them. There is no standard global definition of food subgroups, and no universal definition of 'how different is different enough'.

Besides distinguishing nutritionally, food subgroups should be widely recognizable to nutritionists, globally, such that they could be referred to in population-level guidance. National authorities need to translate global guidance and develop messages, but this should be enabled by sensible selection of food subgroups in global exercises such as this one.

In developing the list of subgroups, we considered the food subgroups used in the US food pattern modeling exercise (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020), the food subgroups used in the Australian national food pattern modeling exercise (Dieticians Association of Australia 2011), the food subgroups used in previous Optifood studies (and coded in the Optifood food composition database), and the food groups in the WHO/UNICEF infant and young child feeding (IYCF) dietary diversity indicator (WHO 2021).

In addition, for Optifood modeling, further division into subgroups is also advisable when quantities (gram weights consumed per day) are likely to differ among types of items (for example, breads vs. dry cereal grains).

Our initial subgroups were further revised after we developed preliminary nutrient profiles for the subgroups and examined item outliers and other nutrient patterns within subgroups. For example, nutrient profiles for liver differed greatly from those for other organ meats, and other organ meats were even more rarely consumed, so we chose to narrow an initial 'organ meat' subgroup group to 'liver'.

Finally, global culinary uses, which relate to typical quantities consumed, were also considered. For example, peppers and tomatoes (fruits in the Solanaceae family) were grouped together because they are present in many cuisines as common sauce ingredients but are higher in vitamins A and C than onions (another common sauce ingredient); onions were classified with 'other vegetables'.

Table 6 (next page) provides a summary of the food groups and subgroups. **Annex 3** provides further details, including on exclusions of items from each group, and operational definitions of certain terms such as 'whole grain'.

Table 6. Core food groups and subgroups

Starchy staple foods
Whole grains, including flours, pasta, rice, and other grains
Refined grains, including flours, pasta, rice, and other grains
Whole grain dry breakfast cereals, including oats
Refined grain dry breakfast cereals
Whole-grain savory bakery products (breads and similar)
Refined-grain savory bakery products (breads and similar)
White-colored starchy roots, tubers, and plantains
Fruits
Vitamin A-rich fruits (e.g., apricot, cantaloupe, mango, papaya, passion fruit)
Berries
Citrus
Other vitamin C-rich fruits (e.g., guava, kiwi, longan, litchi)
Bananas
Avocado and coconut (flesh) and any other high-fat fruits
Other fruit (e.g., apples, peaches, pears, pineapple, others)
Vegetables
Medium to dark green leafy vegetables
Other *Brassicas* (e.g., broccoli, cauliflower, cabbage, brussels sprouts, kohlrabi, but not roots/tubers)
Vitamin A-rich orange vegetables (e.g., carrots, squash, pumpkin, and orange-fleshed sweet potato)
Peppers and tomatoes
Immature peas and beans (seeds and pods)
Other vegetables (e.g., cucumbers, onions, corn, mushrooms, turnip, iceberg lettuce, other)
Dairy products
Milk
Yogurt (also including other fermented dairy such as kefir or buttermilk)
Cheese
Protein foods
Eggs
Legumes/pulses, and flours made from these
Soy foods
Peanuts/groundnuts, tree nuts, and seeds, and pastes made from these
Beef, lamb, mutton, goat, and large and small game meat
Pork
Poultry and wild birds
Liver
Fish, small, eaten with bones
Fish, larger, not eaten with bones
Added fats and oils
Solid fats and highly saturated oils
Most vegetable oils (unhydrogenated)

2a.5.4. Other items not used in initial models

In addition to the food groups and subgroups above, the full food item listing (see below) included additional items, namely unhealthy food and beverage items consumed by infants and young children (IYC).

Unhealthy food and beverage items were further grouped as:

- Sweet beverages (non-dairy)
- Sweet baker's confections (cakes, sweet biscuits/cookies, sweet donuts, etc.)
- Sugar confections (candies, jellies, chocolate)
- Salty and/or fried snack foods and fast foods (chips, crisps, fried savory snacks, instant noodles, etc.)

These groups are generally aligned with the sentinel unhealthy beverages and foods captured in the WHO/UNICEF IYCF indicators (WHO 2021). We did not develop nutrient profiles for these subgroups as a whole, but instead selected certain items to 'force in' at later stages of modeling (details below).

In addition to the food groups above and the sentinel unhealthy items, selected fortified items were included in later stages of the modeling (details below).

2b. Other modeling inputs and parameters

This section describes development of a series of resources required for specification of the remaining modeling parameters. Unlike the parameters in Section 2a, those in this section required collation and analyses of data and information from a very wide range of sources. We developed several key intermediate products, including:

- A global food item list
- A food composition database
- A set of food subgroup nutrient profiles
- Prevalence of consumption and distributions of daily intakes in grams by IYC at the food subgroup level

The last of these was the basis for specification of Optifood modeling parameters for:

- Maximum daily quantity per food subgroup
- Frequencies of consumption, per week, for food groups and subgroups.

Development of intermediate products and resulting quantity and frequency parameters are described here and further detailed in a series of Annexes.

2b.1. Food item list

2b.1.1. Data sources for the food item list

Information on infant and young child diets was compiled from a variety of public sources and by soliciting additional data and information from colleagues. Sources are outlined here and described in detail in **Annex 4**.

Quantitative 24-hour recall data for infants and young children were available from:

- The WHO/FAO Global Individual Food Consumption data Tool (GIFT), at: https://www.fao.org/gift-individual-food-consumption/en/
- The Global Dietary Database, at: https://www.globaldietarydatabase.org/
- The International Food Policy Research Institute Dataverse, housed within the Harvard Dataverse Repository, at: https://dataverse.harvard.edu/dataverse/IFPRI

- National studies for the US (https://www.cdc.gov/nchs/nhanes/index.htm) and the UK (https://ukdataservice.ac.uk/)
- Study data from Malawi and Peru, provided by colleagues

Unpublished data on prevalence of consumption of food items was provided by:

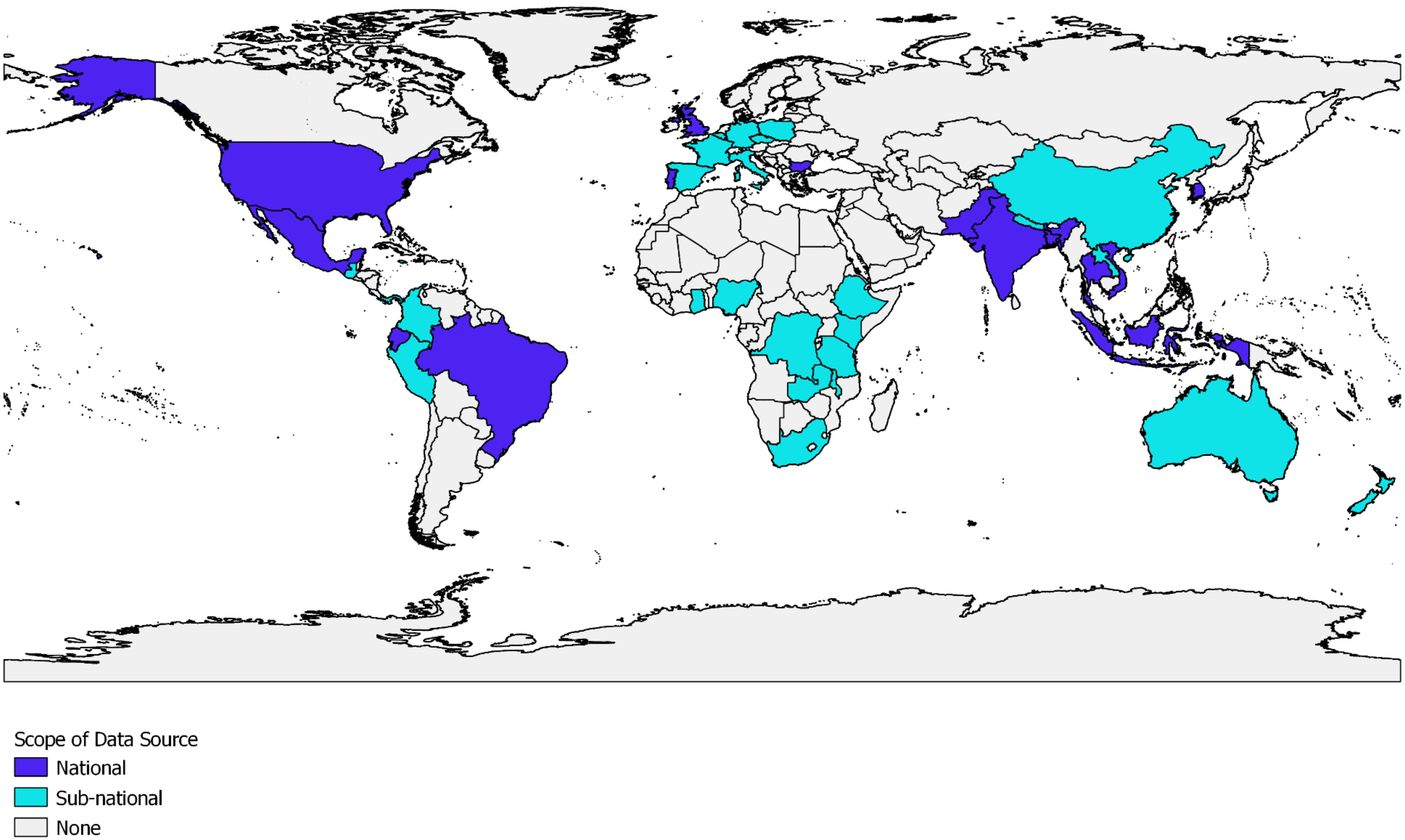
- Helen Keller International's Assessment and Research on Child Feeding (ARCH) project team; information on grams consumed per day was also provided for food items for one country (Nepal)
- The Brazilian National Survey on Child Nutrition (ENANI-2019) study team

Food item lists, with or without prevalence of consumption, and with or without information on quantities consumed, were available from a wide range of sources including:

- Reports and articles from previous Optifood studies that aimed to develop food-based recommendations for infant and young child feeding
- Studies employing the Process for Promotion of Child Feeding (ProPAN) tool developed by the Pan American Health Organization and partners
- Formative studies undertaken for the Enhancing Nutrition Services to Improve Maternal and Child Health (ENRICH) initiative of Nutrition International and partners
- Published journal articles obtained from a limited literature review

Combining lists from all sources, food items were available from 37 countries and one multi-country study from Europe. **Figure 1** summarizes the geographic distribution of the sources and indicates which were at national and which at sub-national level.

Figure 1. Geographic distribution of sources



2b.1.2. Development of the food item list

The objective in developing a global food item list was to ensure that food subgroup nutrient profiles would reflect food items consumed by infants and young children from a wide range of food cultures, from diverse geographic areas and country income levels. An exhaustive list was infeasible for several reasons, including that any item in the list would then have needed to be matched to appropriate food composition data. However, a reasonably comprehensive list, including food items from multiple countries in each major geographic region, was achievable.

Since mixed dishes vary far too widely globally, they were not included in the food item list. Instead, ingredients in mixed dishes were included whenever possible, that is, when researchers had previously disaggregated mixed dishes into their component parts in our data sources. The available data sets and food item lists varied in respect to this.

Steps in developing the list were:

- Extraction of food item lists from the diverse sources described above
- Exclusion of rarely consumed items[9]
- Categorical exclusion of items (condiments, mixed dishes, others – see Annex 3 for details)
- Categorization of food items into the food groups and subgroups in Table 6
- Matching of each food item to an appropriate item in a food composition database

During matching, as was done in the US food pattern modeling exercise, less healthy items were matched to healthier alternatives in the food composition databases (see below for development of the food composition database). For example, fried meats were matched to stewed or braised items; 'processed cheese foods' were matched to unprocessed cheese, etc.). Also following the US example, for each type of animal meat we matched all forms to one item (for example, all types of beef to one item, all forms of pork to one item, etc.[10] However, we retained diversity in most food groups/subgroups (particularly fruits, vegetables, legumes, and fish).

In addition, and differently from in the US exercise, fortified items were matched to non-fortified items. This is because levels of fortification vary widely, globally. In addition, our initial objective was to identify gaps in unfortified diets. Our initial models therefore included only unfortified foods, with fortified items designed for infants and young children added in a later stage of modeling.

Table 7 presents the number of unique food items in the list for each food subgroup. These numbers represent the list of items after exclusions and also after a certain level of 'clustering' of similar items; see **Annex 5** for further details.

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[9] Where possible, this was defined as food items consumed by fewer than 5% of infants and young children. Items consumed by at least 5% in either of 2 age subgroups (6-11.9 months and 12-23.9 months) were included. Some sources used other cut-offs for defining 'rare' items (for example, <3% or <10%) and in these cases, since we did not have access to data, we accepted researcher definitions of rare items and excluded them. In other cases (Optifood, ProPAN, and ENRICH studies) researchers purposefully included nutrient-dense items in lists even if rarely consumed, so long as they were consumed by any children and were considered acceptable and feasible for promotion. We also included these items. All other items listed in Optifood studies were consumed by at least 5% of infants and young children. See Annex 4 for additional details.

[10] In the US food pattern modeling exercise, one specific item was used, for example, for all beef. Instead of this, we created average items by averaging nutrient values across a set of items; see Annex 5 for details.

Table 7. Number of food items per food subgroup[a]

Food subgroup	# Items	Food subgroup	# Items
Whole grains	26	Milk	7
Refined grains	19	Yogurt	5
Whole grain breakfast cereals	5	Cheese	12
Refined grain breakfast cereals	7		
Whole grain bakery products	14	Eggs	4
Refined grain bakery products	4	Legumes	20
Starchy roots, tubers, plantains	14	Soy foods	3
		Nuts and seeds	15
Vitamin A-rich fruits	10	Beef, lamb, goat, game	12
Berries	9	Pork	2
Citrus	5	Poultry	7
Vitamin C-rich fruits	4	Liver	3
Bananas	2	Small fish	10
High-fat fruits	3	Larger fish	39
Other fruits	24		
		Solid fats and saturated oils	9
Dark green leafy vegetables	37	Other vegetable oils	11
Other brassicas	4		
Vitamin A-rich orange vegetables	4		
Peppers and tomatoes	8		
Peas and beans (immature seeds/pods)	8		
Other vegetables	38		

[a] See Table 6 for longer food subgroup names, and Annex 3 for additional details on operational definitions of subgroups, and on exclusions.

The food subgroups in Table 7 were all used in the initial modeling of 'best-case' food patterns. In addition, later stages of modeling included 1) sentinel unhealthy foods and beverages; and 2) fortified items.

2b.1.3. Sentinel unhealthy items

For sentinel unhealthy items, we did not develop comprehensive nutrient profiles incorporating all items consumed, but identified examples as follows:

1. Based on review of the data sources described above, we identified three of the most commonly consumed general types of unhealthy items - sugar-sweetened beverages, sweet biscuits, and fried crisps or chips.
2. For each of these three, we averaged across several example items. For example, for sugar-sweetened beverages (SSB), we averaged across available nutrient composition data for a juice drink and a sugar-sweetened carbonated drink (soda), as these were among the most commonly consumed SSB.

See Annex 5 for further details and nutrient composition data for these sentinel unhealthy items.

2b.1.4. Fortified items

Based on input from the GDG, the following fortified items were included:

- A multiple micronutrient powder (MNP)
- A small-quantity lipid-based nutrient supplement (SQ-LNS)
- A fortified cereal-based product targeted to IYC (Super Cereal Plus)

See Annex 5 for discussion of sources of nutrient composition data for the specific fortified products selected for use in modeling.

2b.2. Food composition database

All items in the food item list needed to be matched to appropriate food composition data. Food composition databases vary widely across countries in the number of nutrients included, units of measure, standards for sampling and analytic methods, and documentation.

Currently there is no comprehensive global food composition database. The FAO maintains an archive providing links to national and regional food composition databases and also provides several partial databases developed by FAO for global use (see: https://www.fao.org/infoods/infoods/tables-and-databases/en/).

We downloaded all food composition databases available from or linked to the FAO archive as of 16 November, 2021. We did not otherwise search for national food composition databases. We also had access to the Optifood internal food composition database, developed for previous Optifood studies, and to several project-specific food composition databases provided by colleagues.

Given the scope of our own project, we needed to select a single primary source for nutrient composition data. For practical reasons we selected US food composition data as our primary source. We augmented this when food items on our list had no good match in the US data. In addition, since the US food supply is highly fortified for certain foods (for example, grain-based foods and dairy), we sought nutrient data for some items from other countries (primarily Germany) with available unfortified/unenriched items.

When there was no good match for a given food item in either of two US databases,[11] we searched other databases in the following general order of preference:

- National food composition databases from the relevant country
- Regional food composition databases (the West African and the Southeast Asian (ASEAN) databases)
- The Optifood internal food composition database
- The FAO global, biodiversity, and fish food composition databases
- Project databases, and up to one other national database from a neighboring country

For example, fresh mangosteen and rambutan fruits were reported to be consumed in several Asian studies but the US databases lacked nutrient data. We did not have national food composition data for the relevant countries, so we took nutrient values from the ASEAN food composition database.

[11] We used the Standard Reference 28 – also referred to as the SR Legacy database – as our primary reference, followed by the survey-linked database called the Food and Nutrient Database for Dietary Studies (FNDDS; 2017-2018 survey round). Both are available from: https://fdc.nal.usda.gov/download-datasets.html.

Annex 5 provides further details on the development of the food composition database, including on the following topics:

- Number and proportion of nutrient values from each source database
- Selected forms of foods per food subgroup, and the use of yield and retention factors
- Item clustering, and matching to food composition data
- Handling of missing values for nutrient data
- Selection of nutrient values for fortified products and sentinel unhealthy items
- Citations for all food composition databases

The final food item list included 404 items, representing foods consumed by IYC in one or more of the 37 countries from which we had food item lists. However, 24 of these food items were not described with sufficient specificity to match them to nutrient values (for example, if the data source indicated 'fish'). Therefore, the food composition database includes 380 sets of nutrient values for unique items. This total does not include the items added for use only in later stages of modeling (sentinel unhealthy items and fortified items).

2b.3. Food subgroup nutrient profiles

Once the food item list was compiled and matched to appropriate food composition data, we calculated subgroup nutrient profiles as follows:[12] We first 'stacked' food items lists from all sources, then collapsed the full food item list to the level of unique items within each country.[13] In this collapsed list, a food item and its associated nutrient data could be represented multiple times, depending on the number of countries in which the food item was reported.

We then calculated the mean nutrient value for each nutrient, for each food subgroup. These subgroup nutrient means were 'self-weighted' by the number of countries in which each item was consumed. This self-weighting ensured that items consumed in only one or a few countries were not given the same 'weight' in the nutrient profiles as those consumed very widely, or everywhere.

For example, carrots were reported to be consumed by IYC in 27 of 37 countries, compared to 15 of 37 countries for pumpkin. Carrots therefore had nearly double the weight of pumpkin in calculating an average nutrient profile for the vitamin A-rich orange vegetables subgroup.

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[12] There is a preferred approach that was infeasible in our context. In some national food pattern modeling exercises, nutrient profiles have been informed by nationally representative dietary intake data (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020; Dieticians Association of Australia 2011). For example, in the Australian food pattern modeling, to develop nutrient profiles individual food items within a subgroup or group were weighted by their relative percent contribution by weight to the food group consumption, for each age group modeled. Our available data were not sufficient to use in this type of weighting exercise, due to the many methodological differences across our data sources. In particular, the level specificity in food item descriptions and the level of 'clustering' of items varied widely, as did the proportion of composite foods disaggregated into ingredients. Also, we did not have data on gram intakes from all of our sources for the food item lists. For these and other reasons, we could not calculate weighted nutrient profiles as was done in the national examples.

[13] Within a country, food items could be listed more than once if we had multiple data sources for the country (for example, from different regions) and/or if multiple food items were 'clustered' and assigned the same representative item in the compiled food composition database (for example, we used nutrient values for 'winged game, unspecified' from the French food composition database as a representative item for grouse, pheasant, quail, etc.).

Draft nutrient profiles were then examined to identify any undue influence of nutrient outliers within each food subgroup. In a small number of cases, food composition data were replaced with values from an alternate source; in rare cases, nutrient values were coded as missing when deemed to be implausible. See **Annex 6** for details.

Review of draft nutrient profiles also resulted in two changes to our set of food subgroups, due to high heterogeneity and/or the presence of outliers. Specifically:

- The food subgroup for organ meats was narrowed to liver
- The food subgroup for fish and seafood was narrowed to fish

The excluded food items – organ meats other than liver, and seafood (crustaceans, bivalves, cephalopods and snails) – were not consumed or very rarely consumed in a majority of the countries for which we had data (see Annex 3 for more details).

Tables 8 and 9 present the subgroup nutrient profiles for the target nutrients. Nutrient profiles are for foods as eaten, with the exception of the whole grain, refined grain, and legumes groups. For these groups, we used nutrient values for dry forms because water content is otherwise too variable (for example, there is a wide range of water content in porridges). However, we assumed these foods would be eaten boiled, and applied retention factors such that the nutrient profiles are for retention-adjusted dry forms. When defining quantities (Sections 2b.4 and 2b.5, below), we also used dry weight for these food groups.

For the analyses exploring single staple foods, we selected specific food items for rice-based and maize-based diets (that is, the nutrient profile was the nutrient content of a single item) but used the nutrient profile for roots, tubers and plantains. See Annex 6 for details.

Annex 6 provides further details, including the item lists and 'weighting' (that is, number of countries where each item was reported to be consumed), and also presents nutrient profiles for non-target nutrients and for unhealthy and fortified items.

Table 8. Nutrient profiles for Optifood modeling: Energy and target minerals

	Energy (kcal)	Fat (g)	Calcium (mg)	Iron (mg)	Potassium (mg)	Zinc (mg)
Starchy staple foods						
Whole grains	359	3.4	26.1	2.89	312	2.1
Refined grains	366	1.0	16.7	0.98	93	1.0
Whole grain breakfast cereals	370	5.5	52.9	3.74	353	3.5
Refined grain breakfast cereals	366	1.0	16.7	0.98	93	1.0
Whole grain bakery products	215	2.6	35.0	2.17	219	1.4
Refined grain bakery products	253	2.4	25.3	0.71	123	0.7
Starchy roots, tubers, plantains	107	0.1	13.1	0.50	317	0.3
Fruits						
Vitamin A-rich fruits	54	0.3	13.7	0.34	201	0.1
Berries	41	0.3	17.1	0.50	144	0.2
Citrus	48	0.2	38.0	0.12	175	0.1
Vitamin C-rich fruits	66	0.7	23.7	0.30	347	0.2
Bananas	89	0.3	5.0	0.26	355	0.2
High-fat fruits	223	20.3	15.1	1.11	433	0.8
Other fruits	51	0.2	8.2	0.25	133	0.1
Vegetables						
Dark green leafy vegetables	30	0.4	125.4	2.50	366	0.5
Other brassicas	28	0.3	35.5	0.43	220	0.3
Vitamin A-rich orange vegetables	38	0.2	24.7	0.47	234	0.2
Peppers and tomatoes	21	0.2	10.0	0.41	212	0.2
Peas and beans (immature pods)	65	0.3	42.7	1.35	227	0.7
Other vegetables	37	0.4	23.6	0.53	208	0.3
Dairy products						
Milk	67	3.9	124.2	0.07	147	0.4
Yogurt	69	3.7	120.1	0.05	157	0.5
Cheese	308	24.3	521.9	0.29	106	3.1
Protein foods						
Eggs	158	11.0	53.4	1.61	139	1.2
Legumes	347	1.8	91.3	5.56	837	2.8
Soy foods	137	7.0	134.0	3.16	497	1.1
Nuts and seeds	579	49.0	154.1	4.16	637	4.1
Beef, lamb, goat, game	197	7.5	13.4	3.05	306	6.6
Pork	190	7.1	20.7	0.94	361	2.6
Poultry	179	7.1	13.7	1.46	209	2.1
Liver	175	5.5	8.9	11.68	261	5.3
Small fish	181	7.3	457.4	3.78	386	2.6
Larger fish	139	5.3	32.1	0.87	331	0.8
Added fats and oils						
Solid fats and saturated oils	800	90.2	6.6	0.03	11	0.0
Other vegetable oils	885	100.0	0.1	0.09	0	0.0

Table 9. Nutrient profiles for Optifood modeling: Target vitamins and choline

	Vit. A (µg RE)	Thiamin (mg)	Riboflavin (mg)	Vit. B6 (mg)	Folate (µg)	Choline (mg)	Vit. B12 (µg)	Vit. C (mg)
Starchy staple foods								
Whole grains	2.7	0.29	0.14	0.35	23.16	25.2	0.00	0.1
Refined grains	1.2	0.08	0.05	0.11	12.84	6.7	0.00	0.0
Whole grain breakfast cereals	0.0	0.35	0.13	0.12	27.24	36.6	0.00	0.0
Refined grain breakfast cereals	1.2	0.08	0.05	0.11	12.84	6.7	0.00	0.0
Whole grain bakery products	1.4	0.20	0.13	0.15	28.10	18.3	0.00	0.0
Refined grain bakery products	0.0	0.09	0.06	0.02	20.72	13.2	0.00	0.0
Starchy roots, tubers, plantains	11.5	0.08	0.03	0.21	16.69	14.6	0.00	7.7
Fruits								
Vitamin A-rich fruits	173.6	0.02	0.04	0.09	30.02	6.6	0.00	36.9
Berries	5.0	0.03	0.03	0.04	17.09	6.6	0.00	38.7
Citrus	37.1	0.08	0.04	0.06	25.15	8.9	0.00	44.2
Vitamin C-rich fruits	32.4	0.04	0.04	0.09	36.21	7.7	0.00	153.0
Bananas	5.9	0.03	0.07	0.36	19.17	9.8	0.00	8.5
High-fat fruits	9.8	0.07	0.10	0.19	64.08	13.6	0.00	8.3
Other fruits	12.7	0.03	0.03	0.05	5.38	4.5	0.00	7.5
Vegetables								
Dark green leafy vegetables	620.7	0.08	0.16	0.18	72.24	14.4	0.00	19.4
Other brassicas	63.6	0.06	0.08	0.16	64.43	33.7	0.00	50.5
Vit. A-rich orange vegetables	1242.7	0.05	0.06	0.13	12.22	8.7	0.00	6.2
Peppers and tomatoes	96.6	0.04	0.02	0.13	14.69	6.7	0.00	49.5
Peas & beans (immature)	68.5	0.16	0.12	0.13	50.51	23.8	0.00	14.3
Other vegetables	19.4	0.05	0.05	0.10	28.97	12.5	0.00	7.6
Dairy products								
Milk	51.0	0.04	0.17	0.04	8.02	15.3	0.37	1.8
Yogurt	30.7	0.04	0.18	0.05	9.74	16.9	0.41	1.0
Cheese	254.7	0.04	0.37	0.10	23.00	15.8	1.65	0.0
Protein foods								
Eggs	155.6	0.08	0.52	0.13	45.84	288.7	1.50	0.0
Legumes	4.1	0.45	0.17	0.28	247.55	90.9	0.00	1.9
Soy foods	1.1	0.13	0.23	0.16	51.22	47.2	0.00	0.7
Nuts and seeds	1.0	0.34	0.28	0.42	96.99	55.4	0.00	0.5
Beef, lamb, goat, game	2.5	0.06	0.22	0.33	9.37	116.0	2.60	0.2
Pork	1.5	0.55	0.33	0.52	1.56	97.0	0.67	0.1
Poultry	16.4	0.07	0.19	0.35	5.51	75.5	0.32	0.4
Liver	6333.2	0.25	2.56	0.79	341.24	358.0	36.35	17.5
Small fish	50.6	0.08	0.29	0.20	12.15	80.0	8.58	0.2
Larger fish	19.8	0.08	0.13	0.32	10.59	76.0	4.37	0.6
Added fats and oils								
Solid fats and saturated oils	226.1	0.01	0.02	0.00	0.95	12.7	0.07	0.1
Other vegetable oils	0.0	0.00	0.00	0.00	0.00	0.2	0.00	0.0

2b.4. Prevalence of consumption and daily intakes in grams

Data on prevalence of consumption and on daily intakes in grams provided the basis for specification of Optifood modeling parameters for maximum quantities and frequencies of consumption for food groups and subgroups. These parameters were developed primarily based on our own analysis of available quantitative dietary intake data sets, listed above, and detailed in Annex 4, Table A4.1. We augmented our analyses with limited use of published information on percent consuming and median gram intakes from a wider range of sources (see Annex 4, Table A4.2 and **Annex 7** for explanation of limitations in use of these information sources).

In our analyses, survey weights were applied when available and appropriate. All analyses were performed separately for infants 6-11.9 months and children 12-23.9 months of age. Sample sizes did not allow separate examination of intake distributions for infants 6-8.9 and 9-11.9 months of age. Due to the many differences in methodology and scope, data sets were not 'stacked' but were analyzed separately.[14]

For each data set, we coded items into food subgroups, applying yield factors as needed before collapsing the files to the food subgroup level. We then determined prevalence of consumption of each food subgroup, as well as median daily intakes in grams. These data on prevalence and on median consumption of food subgroups among consumers were used to inform selection of parameters.

2b.5. Specification of maximum quantities and frequencies of consumption

For food subgroups and the five broader food groups, Optifood required definition of the following parameters:

- Median grams per day at the food subgroup level; referred to below as 'daily servings'
- Maximum number of days in the week the food subgroup can be consumed
- Maximum number of daily servings per week, at the level of the broad food group

Modeling is for a weekly food pattern rather than a daily one. For each food subgroup, the median grams per day is multiplied by the maximum days per week to yield the maximum grams per week. The Optifood model solution cannot exceed this amount. In model solutions, the selected grams per week for the subgroup could later be expressed in terms of servings per day or per week based on local/national serving sizes, as desired. But the model solution is in grams per week.

Similarly, maxima at the broad food group level were also defined on a weekly basis. This combination of subgroup- and group-level constraints allowed the model flexibility in selecting subgroups within a group, while not exceeding feasible totals at either the subgroup or the broad food group level.

For all models, minimum grams and minimum frequencies were set to zero for food groups and subgroups, with two exceptions:

1. Grams of breast milk were a fixed quantity per scenario, as detailed in Table 2, and breastfed infants in a given age and energy intake group were assumed to be fed the same gram amount daily (seven days a week);[15]

[14] The one exception to this was for Kenya, where we had several data sets from very different parts of Kenya and where dietary methodologies were similar; these data sets were combined.

[15] For technical reasons related to the software, the minimum and maximum quantities per week must differ, so the minimum frequency for breast milk was set to 6.9999 days and the maximum to 7.0001 days a week.

2. For starchy staple foods, a minimum was set at one-half of a daily serving per day,[16] reflecting the fact that in most contexts first foods will include starchy staple foods; we judged that model solutions with no staple foods would lack face validity.

For most food subgroups, we had two objectives in setting the maximum quantity and frequency constraints:

1. We aimed to select constraints that reflected quantities that are consumable by the age group, as evidenced by the observed distributions of consumption in grams in various settings; and
2. For most food subgroups, we aimed to allow for generous amounts, to maximize the possibility that nutrient needs could be met.

The exception to the second objective was for fluid milk for breastfed IYC. Fluid milk may displace breast milk, and in some countries is not recommended before 12 months of age. Yet, mixing milk or milk powder in porridges is promoted in some countries. Parameters for maximum quantities of fluid milk for breastfed infants were set after consultation with WHO staff and considering concerns about displacement.

We did not aim to create food patterns that reflected any one setting, but rather food patterns that allowed for selection of feasible but high quantities of nutrient-dense foods. In general, we followed the Optifood approach to developing these parameters, with some modifications related to our objectives and the nature of the available data. In summary:

- Maximum daily serving sizes in grams for each food subgroup were selected based on examination of median gram intakes in several countries where gram intakes for the subgroup were highest;
- For food subgroups, the maximum number of days per week the food subgroup could be consumed was estimated based on prevalence of consumption in the country where prevalence was highest, using the method of Skau et al. (2014);
- For food groups, the maximum number of daily servings per week from any/all subgroups in the group was estimated based on extrapolating from information on the number of subgroups consumed on the recall day.

See Annex 7 for details on each of these. **Box 1** presents an example calculation of subgroup parameters, and **Table 10** presents the quantity and frequency parameters for core food groups and subgroups. Most quantities in Table 10 are for foods as consumed (for example, fresh raw fruits, boiled roots/tubers, or braised meats). However, quantities for grains and legumes are given in dry form, as in the nutrient profiles in Tables 8 and 9.

[16] This was set at one-half serving in recognition that smaller, younger children within each age group should not have a minimum serving based on a generous daily serving size determined for the entire age group.

Box 1. Example calculation of quantitative parameters for eggs

To set a daily serving in grams, we took the average of the two highest medians:

- 6-11.9 months: 40 g, average of median intakes among consumers in Bangladesh and Mexico
- 12-23.9 months: 50 g, average of median intakes among consumers in Ecuador and Mexico

We based the maximum number of daily servings per week on the percent consuming in the country with the highest prevalence of consumption:

- 6-11.9 months: 50%, in Bulgaria
- 12-23.9 months: 69%, in Bulgaria

Based on the method of Skau et al. (2014), this results in maximum daily servings per week of 6 and 7 for the two age groups, respectively, yielding the following maximum total grams of eggs per week:

- 6-11.9 months: 240 g
- 12-23.9 months: 350 g

A medium egg is ~45 g and a large egg is ~50 g, so these parameters would allow infants 6-11.9 months of age to have, at most, an egg ~ 5 days per week, and children 12-23.9 months of age could have an egg, at most, daily.

Table 10. Modeling parameters: maximum grams per day and days per week for food subgroups, and minimum and maximum number of daily servings per week at food group level

	6-11.9 mo				12-23.9 mo			
Food groups and subgroups	**Max. g/d**	**Max. d/wk**	**Min. # serves/ wk**	**Max. # serves/ wk**	**Max. g/d**	**Max. d/wk**	**Min. # serves/ wk**	**Max. # serves/ wk**
Starchy staple foods			3.5	21			3.5	21
Whole grains	35	7			65	7		
Refined grains	35	7			65	7		
Whole grain breakfast cereals	15	6			20	6		
Refined grain breakfast cereals	15	6			20	6		
Whole grain bakery products	35	6			50	7		
Refined grain bakery products	35	6			50	7		
Starchy roots, tubers, plantains	60	7			70	7		
Fruits			0	14			0	17.5
Vitamin A-rich fruits	60	3			145	4		
Berries	25	2			65	3		
Citrus	65	2			100	4		
Vitamin C-rich fruits	30	1			40	2		
Bananas	70	6			100	7		
High-fat fruits	60	2			60	4		
Other fruits	90	7			100	7		
Vegetables			0	24.5			0	28
Dark green leafy vegetables	40	4			60	7		
Other brassicas	25	6			60	6		
Vitamin A-rich orange vegetables	60	7			80	7		
Peppers and tomatoes	25	6			40	7		
Peas and beans (immature pods)	40	4			40	4		
Other vegetables	40	7			40	7		
Dairy			0	14			0	17.5
Milk[a]	60/120	7			240/475	7		
Yogurt[a]	60/120	6			120	7		
Cheese	25	6			25	7		
Protein foods			0	14			0	21
Eggs	40	6			50	7		
Legumes	25	4			30	6		
Soy foods[b]	25	2			20	3		
Nuts and seeds	10	4			20	6		
Beef, lamb, goat, game	30	3			40	5		
Pork	30	3			35	5		
Poultry	45	6			60	6		
Liver	20	2			20	2		
Small fish	15	3			50	6		
Larger fish	35	3			50	6		

Added fats and oils			0	10.5			0	14
Solid fats and saturated oils[b]	6	7			6	7		
Other vegetable oils	6	7			10	7		

[a] For infants, the lower values for milk and yogurt are the maxima for ages 6-8.9 months and the higher for ages 9-11.9 months. For children, the lower value for milk is the maximum for breastfed children and the higher for non-breastfed children.

[b] For soy foods and for solid fats and saturated oils, there was an error in the model parameters used for children 12-23.9 months of age. The maximum grams per day should have been 30 for soy foods, rather than 20, and 11 for solid fats, rather than 6. We discovered this error after the report was near completion. We reran models using the correct parameters and confirmed that these small differences did not change our results identifying nutrients below NRVs, and changes to food patterns were very minor. None of our key results were affected by the error.

The parameters in Table 10 were developed to be generous but feasible. Hereafter, we refer to these as 'feasible best-case' food patterns (see **Box 2**). In cases where models based on these parameters resulted in nutrient gaps, we took an additional step to explore whether even more generous weekly quantities could meet the NRVs, hereafter referred to as 'liberalized best-case' food patterns.

For these additional models, we used the same maximum daily quantities, but increased maximum frequencies so that all food subgroups could be selected up to seven times – that is, the maximum daily quantity could be consumed every day. At the food group level, weekly maxima were set at the total number of subgroups within the food group multiplied by seven.

Box 2 presents several definitions introduced in this section.

Box 2. Definitions related to modeled food patterns

Daily serving size
The daily serving size is the amount that an infant or child could consume in one day. To ensure that the daily serving size was a feasible yet generous quantity, we based it on observed median daily intakes from several settings with high intakes of the particular food subgroup. The daily serving size is not defined as the amount that would be offered to an infant or child at one meal. In our modeling, it is used to derive a total quantity for the food subgroup for the week.

Feasible best-case food pattern
The feasible best-case food pattern is feasible in the sense that there is an empirical basis for the maximum quantity and frequency of consumption of food groups and subgroups. It is a best-case pattern in that the quantities and frequencies reflect settings where the food subgroups were more frequently consumed and/or were consumed in larger median quantities. It is also a best-case pattern because it allows inclusion of all nutrient-dense food subgroups, which may not reflect the reality in many settings.

Liberalized best-case food pattern
This food pattern allows weekly consumption in larger amounts, not reflective of the data we examined. These food patterns are reported primarily to answer the question 'Could unfortified foods consumed in larger quantities per week fill nutrient gaps?'

Table 11 presents parameters for the sentinel unhealthy items and the fortified items. For the unhealthy items, the daily serving size was identified in the same way as for the food subgroups; that is, by averaging the two highest median daily serving sizes observed in the available data sets. For models exploring the impact of inclusion of these items, unlike in Table 10, the amount was not an allowed maximum but rather was fixed. Similarly, the amount was fixed for the fortified items. For MNPs and SQ-LNS, the amount was one sachet/dose. For the Super Cereal Plus, the amount was the maximum value in Table 10 for grains, flours, etc.

The sentinel unhealthy items, the MNPs, and the SQ-LNS were not considered as fitting under any of the core food groups. However, Super Cereal Plus is designed as a staple food, so it was coded as a staple and could count toward meeting the minimum required quantity of staples. This meant it could also displace all other staple foods. For scenarios with the other fortified items and the unhealthy items, there was still a minimum of 3.5 daily servings per week of starchy staple foods, which could not be displaced.

The parameter for the number of days per week (and thus total grams per week) was iteratively increased to explore impacts on nutrient gaps of varying frequency of consumption of these items.

Table 11. Modeling parameters for sentinel unhealthy items and fortified items[a]

	6-11.9 mo		12-23.9 mo	
	g/d	**d/wk**	**g/d**	**d/wk**
Sentinel unhealthy items				
Sugar-sweetened beverages	110	1, 3, 7	200	1, 3, 7
Sweet biscuits	24	1, 3, 7	36	1, 3, 7
Crisps/chips	12	1, 3, 7	28	1, 3, 7
Fortified items				
MNP – 1 g sachet/dose	1	1, 3, 7	1	1, 3, 7
SQ-LNS – 20 g sachet/dose	20	1, 3, 7	20	1, 3, 7
SCP[b]	35	1, 3, 7	65	1, 3, 7

[a] MNP = multiple micronutrient powder; SQ-LNS = small-quantity lipid-based nutrient supplement; SCP = Super Cereal Plus.

[b] Gram amounts are for dry weight.

2c. Modeled scenarios and descriptive analysis

For all modeled scenarios, the Optifood software produces results that minimize the sum of all gaps[17] between nutrient values in the solution and NRVs for target nutrients. In scenarios where these NRVs can be met, Optifood then minimizes protein. See **Box 3** for further details and implications.

[17] By 'gaps', we mean only gaps where target nutrient intakes in modeled solutions are less than the NRV. Positive deviations from the NRV are not considered as gaps.

Box 3. Implications of Optifood modeling objectives

Primary objecctive
The primary objective for all models was to minimize the sum of all gaps between nutrient values in the model solution and NRVs for target nutrients.

Implications for non-target nutrients
Optifood is 'blind' to all other non-target nutrients, so values in the model solutions may be well below NRVs for these. When developing food-based recommendations, it may be possible to refine food patterns generated by Optifood to address gaps for non-target nutrients, but this was beyond our scope.

Secondary objective
In modeling scenarios where all target NRVs are met, Optifood requires a secondary objective in order to select an optimal result. The secondary objective – built in to Optifood – is to minimize protein.

This secondary objective was selected during design of Optifood as a rough proxy for lowering the cost of the diet, particularly in resource-constrained environments where many protein-rich foods are costly. However, note that many fruits and vegetables may also be costly in these same settings.

Implications of the secondary objective
This secondary objective of reducing protein has certain implications for modeling, which are apparent in our results. Food patterns with minimized protein tend to have fewer animal-source foods and more added fats and oils, because fats and oils do not provide protein.

The feasible best-case models described above (parameters in Table 10) were run for all 12 age/energy level/feeding groups shown in Table 1. The liberalized best-case models were run only for breastfed infants 6-8.9 and 9-11.9 months of age, for all three body size/energy levels. Liberalized models were not run for breastfed or non-breastfed children 12-23.9 months of age because for these children feasible best-case model solutions had no gaps in target nutrients.

Descriptive results for each of the models include:

- The percent of the selected NRV for each nutrient, with problem nutrients defined as those below 98% of the NRV[18]
- Percent of energy from macronutrients
- Percent of energy from broad food groups and subgroups
- Number of food groups and subgroups
- Food subgroups selected
- Frequencies of consumption (number of daily servings) of each subgroup

Further models took the food patterns resulting from the feasible best-case parameters – and not the liberalized parameters – as a starting point and explored the impact on nutrient gaps of various modifications to the food patterns, as shown in **Table 12**. Besides restricting modeling of modifications to the feasible best-case scenarios, we also limited modeling of modifications to the four scenarios at the middle energy intake level. Even with these choices, the total number of models was 149.

[18] Because of the way Optifood works to achieve multiple objectives (multiple NRVs) simultaneously, it is typical for model solutions to have a number of nutrients in the 98-99.9% range. We judged it more meaningful to define problem nutrients as those at less than 98% of the NRV.

Table 12. Summary of questions addressed by modeling[a]

Question	Food patterns/modifications	Foods allowed and/or modified	# of scenarios
Are there nutrient gaps when feasible best-case patterns are modeled?	Modeled feasible best-case patterns, all age/energy level/feeding groups	All food subgroups allowed, empirically-based quantities and frequencies	12
Are there nutrient gaps when liberalized best-case patterns are modeled?	Modeled liberalized best-case patterns for breastfed infants 6-8.9 and 9-11.9 months of age, all energy levels	Increased the allowed number of daily servings per week to seven for all food subgroups	6
What happens when food groups or subgroups are eliminated?	Set maximum grams to zero for one food group, subgroup, or set of subgroups at a time	Whole grain staple foods Vegetables Fruits Fruits and vegetables Legumes, nuts and seeds Dairy Eggs Liver & small fish w/bones Meat, liver, poultry, fish All non-dairy animal source foods	40
What happens when staple foods are monotonous?	Modeled food patterns with only one type of starchy staple food	Maize flour, whole grain, white Rice, white Roots/tubers/plantains	12
What happens if we modify the amount of starchy staple foods?	Modified the minimum number of staple food servings per week for breastfed IYC[b]: 6-8.9 mo: minima of 0, 7, 14, 17 9-11.9 mo: minima of 14, 21 12-23.9 mo: minimum of 21	Starchy staple foods	7
What happens if we add unhealthy foods or beverages?	Set minimum grams for sentinel unhealthy items (previously zero) to a median daily serving, and 'forced in' iteratively at 1, 3, and 7 d/wk	Non-dairy sweetened beverage Sweet biscuits Fried crisps/chips	36
What happens if we add fortified foods or products?	Set minima for fortified foods and products (previously zero) to one dose (MNP, SQ-LNS) or daily serving (SCP), and 'forced in' iteratively at 1, 3, and 7 d/wk	MNP SQ-LNS Super Cereal Plus	36

[a] IYC = infants and young children; MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] We iteratively increased the weekly quantity of staple foods, with the levels depending on the number of servings in the feasible best-case pattern. For infants 6-8.9 months of age, the best-case pattern had the minimum required amount (3.5 per week), so we explored whether lowering the minimum to zero would result in fewer nutrient gaps. We also increased the minimum to 7, 14 and 17, but could not increase to the food group maximum of 21 because this would exceed available kcals from complementary foods. For infants 9-11.9 months of age, the best-case pattern included 7.4 servings, so we increased the minimum to 14, then 21. For breastfed children 12-23.9 months of age, the best-case pattern included 14.5 servings, so we increased the minimum to 21. For non-breastfed children, the best-case pattern already included the food group level maximum of 21 daily servings per week.

For the last question in Table 12 (*What happens if we add fortified foods or products*?), note that the items differ widely in energy content, so displacement effects could also differ. In the case of SQ-LNS, there is no natural food group 'home', so we allowed Optifood to select which items would be displaced, and SQ-LNS could not displace the required minimum amount of staple foods. We modeled Super Cereal Plus as a staple food, so it could replace other staple foods and fulfill the minimum required amount.

In the case of MNPs, which are non-caloric, nutrient needs could be met without displacement, but we chose to model in the same way as for the other fortified items. This meant that for scenarios where nutrient needs were met by MNPs we allowed Optifood to select food subgroups based on the secondary objective of reducing protein.

The food patterns that included these fortified items thus help answer a slightly different question, namely: Can diets lower in protein and in animal-source foods meet target nutrient needs, so long as fortified items are included? This same question is also addressed, in a different way, by the calculations for scenarios approximating real-world food patterns.

2d. Development of scenarios approximating real-world food patterns

Scenarios approximating real-world food patterns required an entirely different approach. Rather than optimizing food patterns to meet nutrient targets, the objectives for this part of the work were to:

1. Characterize nutrient gaps that may be typical in some low- and middle-income settings; and
2. Assess whether fortified items could address nutrient gaps.

While we aimed to approximate real-world food patterns, we created scenarios where energy intakes were sufficient. That is, we used the same EER values as in our modeling work. We also used the same assumption about percent of energy from breast milk.

It was not feasible to create scenarios for all countries or even all global regions. We purposively selected examples from:

South Asia:	Rural Bangladesh, national survey
Southern Africa:	Rural southern Malawi, local study
Latin America:	Mexico, national survey

See Annex 4 for further descriptions of these data sets.

For each of these settings we considered that the available data were of high quality, and in each case the data set included a sufficient sample size in each age group. However, in Malawi, the older age group covered 12-15.9 months of age rather than 12-23.9 months of age.

In Bangladesh and Malawi, breast milk quantities were not available in our data sets. Though they were estimated and included in Mexico, we chose to use the same assumptions about percent of energy from breast milk as in the optimization modeling. **Table 13** shows the prevalence of breastfeeding by age group in each of the data sets. Use of breast milk substitutes was common only in Mexico.

Table 13. Prevalence of breastfeeding in three low- or middle-income settings

	Bangladesh	Malawi	Mexico
6-11.9 mo	97.7	99.9	48.8
12-15.9 mo		98.7	
12-23.9 mo	91.2		13.6

Based on the prevalence of breastfeeding, we chose to create scenarios only for breastfed infants and children in Bangladesh and Malawi. For Mexico, we created scenarios for breastfed infants and for non-breastfed children 12-23.9 months of age. See **Annex 8** for more details.

For each setting, we selected one of the three energy levels for modeling.

- In Bangladesh, mean body weights were closer to those associated with the low energy level.
- In Malawi, body weights for infants were intermediate between the low and middle energy levels but were closer to the low level for the 12-15.9 month age group; we used the low level for all ages.
- In Mexico, mean body weights were nearly identical to those for the middle energy level, and we used this.

For each setting, we then characterized the diet by totaling energy intakes from all complementary foods and beverages and calculating the percent of energy from each food group and subgroup. Certain items that were consumed were excluded, and the energy intake from these was redistributed to other food subgroups, in proportion to their consumption. The main example of this was added sugars. While we included unhealthy items that were reported to be consumed, we 'reallocated' the energy from added sugars. See **Annex 8** for details of exclusions and of the calculations.

Table 14 shows the percent of energy at the major food group level for each setting, with the denominator being all energy from complementary foods and beverages. **Annex 8** details this at the food subgroup level.

Table 14. Percent of complementary food/beverage energy from major food groups in three settings

	Bangladesh		Malawi		Mexico	
Food groups	**6-11.9 mo**	**12-23.9 mo**	**6-11.9 mo**	**12-16.9 mo**	**6-11.9 mo**	**12-23.9 mo**
Starchy staple foods	60	68	66	57	20	25
Fruits	0	0	0	1	9	8
Vegetables	1	2	1	1	4	2
Dairy[a]	16	6	0	1	36	27
Protein foods[b]	5	5	12	13	11	12
Animal-source protein foods	5	4	1	4	8	10
Plant-source protein foods	0	1	11	8	3	3
Added fats and oils	5	7	12	16	4	5
Sentinel unhealthy foods and beverages	13	11	8	11	16	21

[a] Dairy includes milk, yogurt, and cheese. Infant formula, like breast milk, was excluded from the calculations for complementary foods and beverages. Milk was not considered as a breast milk substitute as it is sometimes mixed with porridge or other complementary foods. For Bangladesh and Malawi, the percent of energy from dairy is derived from samples where nearly all IYC were breastfed. In Mexico, only about half of infants were breastfed, but the percent consuming milk was similar between breastfed and non-breastfed infants (16% and 19%, respectively). Most children 12-23.9 months of age in Mexico were not breastfed (84%), so the percent of energy for this group should be close to that for non-breastfed children.

[b] Percents for animal- and plant-source protein foods do not always sum to the total for protein foods due to rounding.

We used the percent of energy at the subgroup level to calculate grams for each subgroup. The grams for each subgroup were multiplied by the associated nutrient profile, then summed across all food subgroups to yield the estimated nutrient content for each scenario. Results include the percent of NRV for all target and non-target nutrients. For iron, we estimated percent of NRV under two assumptions for percent absorption of iron (5% and 10%).

Note that the food patterns developed to address these questions are conceptually very different from those developed by optimization modeling (**Box 4**).

Box 4. Optimization modeling compared to our calculations to approximate real world scenarios

In the optimization modeling we developed generous model parameters based on settings where each food subgroup was most consumed. This was driven by our research questions and the intent to model best-case scenarios for solutions for unfortified diets.

In contrast, when developing food patterns to approximate real-world settings we did not use optimization.

When developing parameters (percent of energy from food groups and subgroups), we did not use serving sizes among consumers only (as during optimization) because consumption of some food subgroups was rare. Use of data from consumers would result in energy levels that would exceed the estimated requirements.

Instead, we developed a population-level estimate of average percent of energy from groups and subgroups. This incorporates information both from consumers and non-consumers (that is. the zeros are included in the averaging).

The resulting food patterns provide insight into nutrient gaps but may include very small quantities, smaller than would be consumed by the portion of the population consuming the given subgroup.

Next, we addressed the second question above by adding fortified products to the food patterns. For all three fortified items, we calculated impacts if given daily.

MNPs provide no energy, so there is no displacement and the nutrients provided by daily MNPs were added to those in the food patterns. This assumes no changes in child feeding when MNPs are given.

At fixed energy intake levels, both SQ-LNS and Super Cereal Plus must displace other food subgroups, isocalorically. We included 20 grams of SQ-LNS (one sachet), providing 118 kilocalories. For Super Cereal Plus, we used the same parameters as in the modeling for the middle energy level scenarios for Mexico, and we decreased this in proportion to the EER for the low energy level scenarios in Bangladesh and Malawi. **Table 15** shows quantities (grams and kilocalories) for Super Cereal Plus.

Table 15. Quantities of Super Cereal Plus used in calculations for scenarios approximating real-world food patterns

	Low energy level			Middle energy level		
	EER[a]	**grams**	**kcal**	**EER**	**grams**	**kcal**
6-8.9 mo	518	28	115	643	35	144
9-11.9 mo	598	29	119	723	35	144
12-23.9 mo	650	49	201	863	65	267

[a] EER = Estimated energy requirement.

For SQ-LNS and Super Cereal Plus, we also needed to make decisions on the order in which food subgroups would be displaced. We considered Super Cereal Plus as a staple food, so staple foods were displaced first, followed by unhealthy items and the other food groups (**Table 16**). The most commonly consumed staple foods (grains, in all three settings) were displaced first. We displaced milk last, because we considered that beverages might be less likely to be displaced (however, we displaced SSB earlier, along with other unhealthy items).

SQ-LNS does not have a natural food group 'home' but is often promoted for use in enriching porridges. Further, we considered it would be difficult for the younger infants to consume SQ-LNS on its own (that is, not mixed with porridge or another soft food). We therefore displaced staple foods last. The order of displacement for other food groups was the same as for Super Cereal Plus.

Table 16. Order for displacement of foods and beverages by fortified items

Super Cereal Plus	**SQ-LNS[a]**
Grains	Biscuits
Bakery products	Crisps
Roots/tubers	SSB
Biscuits	Fruit
Crisps	Cheese
SSB	Yogurt
Fruit	Added fats/oils
Cheese	Vegetables
Yogurt	Legumes
Added fats/oils	Fish
Vegetables	Eggs
Legumes	Poultry
Fish	Pork
Eggs	Beef
Poultry	Liver
Pork	Milk
Beef	Roots/tubers
Liver	Bakery products
Milk	Grains

[a] SQ-LNS = small-quantity lipid-based nutrient supplement.

3. Results

Descriptive results are summarized here, and more extensive tables are provided in **Annex 9**. First, we present results describing gaps between the nutrient content of the model solutions (food patterns) and the NRVs. Next, we provide descriptions of food patterns.

3a. Nutrient gaps

This section summarizes nutrient gaps for both the selected target nutrients and non-target nutrients. Gaps as percent of NRVs are presented here, while Annex 9 provides more complete results for all nutrients, including those for which there are no gaps, and also provides tables with nutrient intakes in absolute amounts.

3a.1. Nutrient gaps in feasible best-case food patterns and liberalized best-case food patterns

For feasible best-case food patterns, the largest gaps between modeled food patterns and NRVs were for **iron** (infants 6-8.9 and 9-11.9 months), **carbohydrate** (most groups) and **vitamin D** (all groups). Carbohydrate and vitamin D were not target nutrients in the modeling. See the discussion section below for further comments on the carbohydrate and vitamin D NRVs and gaps.

All other NRVs were met for the middle and high energy levels (all age/feeding groups). However, for the 6-8.9 month age group with low energy intake, there were additional problem nutrients: the target nutrients **calcium, zinc, and potassium** and one non-target nutrient, **magnesium**.

Under the liberalized best-case food patterns target nutrient gaps were narrowed, but all nutrient gaps remained**.** This means that even when foods such as beef and liver were allowed up to seven days a week, there were significant iron gaps in infancy, and smaller gaps for other minerals for the smallest infants (low energy scenario at age 6-8.9 months). **Table 17** shows the percent of NRV for all nutrients that fell below 98% of the NRV, under any scenario.

For children 12-23.9 months of age, where the best-case patterns had no nutrient gap for iron, food patterns were low in flesh foods (see Section 3b.1, below, for description of food patterns). This could mean that the assumption of 10% absorption for iron, inherent in our selected NRV, was too high. We performed sensitivity analyses with a revised NRV based on an assumption of 5% absorption. For these models, we did not allow flesh foods, because if they are allowed they could be selected in quantities ample to meet iron needs, and the assumption of low absorption is no longer warranted.

Using the revised NRV and modeling with no flesh foods, there was a substantial iron gap for both breastfed and non-breastfed children aged 12-23.9 months (47.3% and 64.9% of the NRV, respectively). Gaps for carbohydrate and vitamin D remained, and there were no other nutrient gaps in these scenarios. See **Annex 10** for more detailed results.

Table 17. Percent of nutrient reference values for problem nutrients under feasible and liberalized best-case food patterns[a]

	Low energy level[b]		Middle energy level[b]		High energy level[b]	
	Feasible	Liberal	Feasible	Liberal	Feasible	Liberal
6-8.9 mo, breastfed						
Target nutrients						
Calcium	74.3	84.6				
Iron	24.3	40.8	27.8	47.4	34.8	52.7
Potassium	86.7	90.3				
Zinc	79.9	86.2				
Non-target nutrients						
Carbohydrate	60.4	60.1	73.3	69.5	93.5	87.6
Magnesium	81.0	88.0				
Vitamin D	4.8	6.8	4.7	10.3	4.4	10.3
9-11.9 mo, breastfed						
Target nutrients						
Iron	36.3	58.3	41.1	64.9	45.4	71.2
Non-target nutrients						
Carbohydrate	72.3	67.2	91.4	79.7		93.2
Vitamin D	4.8	10.3	4.5	10.5	4.4	11.3
12-23.9 mo, breastfed						
Non-target nutrients						
Carbohydrate	60.0		91.6			
Vitamin D	23.7		13.9		1.4	
12-23.9 mo, non-breastfed						
Non-target nutrients						
Carbohydrate	69.7		96.3			
Vitamin D	6.2		2.6		3.1	

[a] Nutrients are included if model results were less than 98% of an NRV for any of the energy intake levels (low, middle or high) either under feasible or liberalized best-case models. Values at or above 98% are not shown. Liberalized models for children 12-23.9 months were not run because there were no gaps in target nutrients in the feasible best-case model results.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age. See Table 2 for the energy content of the modelled diets for each age/feeding group.

3a.2. Nutrient gaps when eliminating selected food subgroups and groups

Table 18 shows the impact of eliminating food groups, subgroups, or combinations one at a time from the feasible best-case food pattern models at the middle energy level for each age/feeding group.

- For the 6-8.9 month old infants, restricting food subgroups resulted in widened gaps (for **iron**, and slightly for **vitamin D**) and in some cases introduced new nutrient gaps (for **thiamin, vitamin B12, copper, magnesium, potassium** and **zinc**). Eliminating whole grains, vegetables, or various flesh foods introduced multiple new gaps.

- For infants 9-11.9 months of age, all NRVs could be met except for **iron**, **carbohydrate**, and **vitamin D** (as in the unrestricted best-case scenario); iron gaps were widened under some scenarios.
- For breastfed children 12-23.9 months of age, gaps for **carbohydrate** and **vitamin D** generally remained, and the NRVs for **fiber**, **iron** and **vitamin B12** were not met under certain food subgroup restrictions.
- For non-breastfed children 12-23.9 months of age, the NRV for **vitamin B12** was not met under several scenarios restricting animal-source foods. In the scenario eliminating all fruits and vegetables, NRVs for **linoleic acid** and **vitamin C** were not met. As for other groups, gaps remained for **carbohydrate** and **vitamin D** under most scenarios.

While some of these gaps are easy to understand (for example, a B12 gap when all animal-source protein foods are eliminated), others are less straightforward and are due to substitution effects. For example, the gap for linoleic acid (a non-target nutrient) occurred because when fruits and vegetables were eliminated Optifood selected more dairy and protein foods and eliminated added oils.

In general, non-intuitive results for nutrient gaps are explained by substitution effects, which can be seen in the results for food patterns, below.

Table 18. Percent of nutrient reference values for problem nutrients when food groups or subgroups are eliminated[a, b]

	All food groups	No whole grain	No vegetables	No fruits	No fruits or vegetables	No legumes nuts seeds	No dairy	No eggs	No liver or small fish	No meat poultry fish	No meat poultry fish eggs
6-8.9 mo, breastfed											
Target nutrients											
Calcium			93.8		93.8		91.3				
Iron	27.8	24.9	17.4	27.8	17.4	26.4	29.4	27.8	20.1	20.7	20.9
Potassium			81.2		81.2						
Zinc		93.8	94.8		94.8				90.8	68.7	65.6
Thiamin		97.8									
Vitamin B12											95.4
Non-target nutrients											
Carbohydrate	73.3	72.0	66.5	73.2	66.5	74.0	75.9	73.2	73.9	78.6	80.6
Copper									87.7		
Magnesium		86.0	71.1		71.1	93.3			96.1		
Vitamin D	4.7	4.9	5.5	4.7	5.5	4.7	4.6	4.7	0.7	1.0	0.3
9-11.9 mo, breastfed											
Target nutrients											
Iron	41.1	38.3	32.3	40.5	31.6	38.4	40.3	41.1	35.3	31.6	30.1
Non-target nutrients											
Carbohydrate	91.4	93.3	90.5	90.7		87.9	94.0	91.4	90.5	85.5	93.6
Vitamin D	4.5	4.5	5.0	4.6	5.1	12.0	8.0	4.5	6.6	8.1	1.0

	All food groups	No whole grain	No vegetables	No fruits	No fruits or vegetables	No legumes nuts seeds	No dairy	No eggs	No liver or small fish	No meat poultry fish	No meat poultry fish eggs
12-23.9 mo, breastfed											
Target nutrients											
Iron			93.8		90.5					94.6	88.2
Vitamin B12											95.0
Non-target nutrients											
Carbohydrate	91.6	81.6	77.1	97.3			90.3		77.7	85.0	91.9
Fiber					96.4						
Vitamin D	13.9	19.9	27.4	16.8	27.7	17.6	19.8	13.9	12.3	12.0	1.5
12-23.9 mo, non-breastfed											
Target nutrients											
Vitamin B12									91.5	91.5	92.5
Vitamin C					80.6						
Non-target nutrients											
Carbohydrate	96.3	81.7	89.2	93.2		96.3	83.2	96.3	97.0	97.0	95.8
Linoleic acid					95.0						
Vitamin D	2.6	2.6	20.0	3.3	32.1	2.6	27.9	2.6	3.9	3.9	2.6

[a] Nutrients are included if model results were less than 98% of an NRV for any of the scenarios. The feasible best-case scenario with all food groups and subgroups allowed is shown for reference. Values at or above 98% are not shown.

[b] All models are for middle energy levels, i.e., the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

3a.3. Nutrient gaps when staple foods are limited in variety or increased in quantity

Because some food patterns are dominated by a single staple food, we explored several scenarios that limited staple foods to a single subgroup (roots, tubers, plantains) or to a single item (whole-grain white maize flour or white rice). For infants and children in the middle energy intake groups, imposing a monotonous staple food resulted in additional gaps for minerals (**calcium, magnesium, potassium**, and **zinc**) only for the youngest age group (**Table 19**).

Table 19. Percent of nutrient reference values for problem nutrients when staples are monotonous[a, b]

	All staples	Only roots tubers plantains	Only whole-grain white maize	Only refined white rice
6-8.9 mo, breastfed				
Target nutrients				
Calcium			83.0	84.5
Iron	27.8	25.0	25.9	22.4
Potassium			97.0	92.4
Zinc		95.5	87.6	76.5
Non-target nutrients				
Carbohydrate	73.3	71.0	79.9	80.6
Magnesium		85.8	93.4	78.7
Vitamin D	4.7	5.0	4.4	4.6
9-11.9 mo, breastfed				
Target nutrients				
Iron	41.1	38.3	38.8	35.8
Non-target nutrients				
Carbohydrate	91.4	93.3	91.7	90.8
Vitamin D	4.5	4.5	4.6	4.6
12-23.9 mo, breastfed				
Non-target nutrients				
Carbohydrate	91.6	81.6	88.5	85.6
Vitamin D	13.9	19.9	24.6	21.6
12-23.9 mo, non-breastfed				
Non-target nutrients				
Carbohydrate	96.3			
Vitamin D	2.6	2.4	3.4	2.5

[a] Nutrients are included if model results were less than 98% of an NRV for any of the scenarios. The feasible best-case scenario with all staple food subgroups allowed is shown for reference. Values at or above 98% are not shown.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

We then explored changing the minimum quantity of staple foods. Our best-case scenarios required at least 3.5 daily servings of any combination of staple food subgroups each week. For each subgroup, the daily serving was based on observed median intakes across the entire age group. We considered 3.5

daily servings weekly (that is, a half serving daily) to be equivalent to a smaller serving of staple foods daily, as would be appropriate for younger, smaller IYC within each age group. In our initial feasible best-case models, the number of daily servings of staple foods selected in model solutions for the middle energy level were:

6-8.9 months:	3.5 daily servings per week (the minimum required)
9-11.9 months:	7.4 daily servings per week
12-23.9 months, breastfed:	14.5 daily servings per week
12-23.9 months, non-breastfed:	21 daily servings per week (the maximum allowed)

To explore the impact of larger amounts of staple foods, we modeled scenarios with higher minima for the first three groups. We did not model for non-breastfed infants 12-23.9 months of age because the feasible best-case scenario already included the maximum of 21 daily servings of staple foods per week (that is, daily servings of three different staple food subgroups in ample amounts).

For infants 6-8.9 months of age, where the minimum required number of servings was selected in the feasible best-case scenario, we also modeled a scenario with a minimum of 0 staple foods to see the impact, if any, on nutrient gaps. For these youngest infants, the maximum number of servings per week that could be modeled was 17, as higher amounts exceeded the total energy available for complementary foods. For older infants and breastfed children 12-23.9 months of age, we modeled up to 21 servings per week.

The models were all for the middle energy level in each age group, and all allowed selection of any of the staple food subgroups. That is, selection of the type of starchy staple was not restricted as in the results immediately above.

Results in **Table 20** show:

- For infants 6-8.9 months of age, lowering the minimum from 3.5 servings per week to zero did not have a positive impact on nutrient gaps. Increasing to seven or 14 daily servings of starchy staples introduced additional gaps for **calcium** and **zinc**, and for the non-target nutrient **magnesium**. Increasing to 17 daily servings widened micronutrient gaps and introduced new gaps for **potassium, thiamin, riboflavin, choline** and **vitamin B6**, and for the non-target nutrient **copper**.
- For infants 9-11.9 months of age, additional staple foods widened the gap for **iron**, but did not introduce any other micronutrient gaps, except for a small gap for **fat**.
- For breastfed children 12-23.9 months of age, increasing to 21 servings did not introduce new gaps.

For infants 6-8.9 months of age, the scenario with 17 servings of staple foods mimics a diet where the infant receives ample breast milk (77% of energy) but the only complementary food is an unenriched grain-based porridge. Gaps could be even more numerous and/or larger if the model excluded whole grains.

Table 20. Percent of nutrient reference values for problem nutrients when staples are increased in quantity[a, b]

	Minimum number of staple food daily servings per week				
6-8.9 mo, breastfed	0 minimum	Best-case (3.5 staples)	7 minimum	14 minimum	17 minimum
Target nutrients					
Calcium			87.3	72.4	66.5
Iron	29.5	27.8	28.4	20.1	12.7
Potassium					78.3
Zinc			97.8	59.5	48.7
Thiamin					84.4
Riboflavin					93.8
Choline					83.4
Vitamin B6					78.0
Non-target nutrients					
Carbohydrate	72.6	73.3	76.6	88.1	89.7
Copper					80.3
Magnesium	96.6			91.1	80.4
Vitamin D	4.7	4.7	4.4	0.7	0.0
9-11.9 mo, breastfed			Best-case (7.4 staples)	14 minimum	21 minimum
Target nutrients					
Fat					96.6
Iron			41.1	38.2	28.5
Non-target nutrients					
Carbohydrate			91.4	91.3	97.9
Vitamin D			4.5	7.3	4.8
12-23.9 mo, breastfed				Best-case (14.5 staples)	21 minimum
Non-target nutrients					
Carbohydrate				91.6	89.7
Vitamin D				13.9	22.5

[a] Nutrients are included if model results were less than 98% of an NRV for any of the scenarios. The feasible best-case scenario is shown for reference (shaded cells). Values at or above 98% are not shown.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

3a.4. Nutrient gaps when sentinel unhealthy items are included

Next, we explored the impact on nutrient gaps if one, three, or seven daily servings of sentinel unhealthy items were included. **Table 21** shows results, with the feasible best-case model results included for comparison.

Except for the youngest age group (6-8.9 months), there were few impacts of inclusion of unhealthy items, and gaps for carbohydrate were eliminated. For infants 9-11.9 months of age, the gap for **iron** was increased, especially with seven servings of sweetened beverages or of biscuits.

For the youngest infants, however, inclusion of sentinel unhealthy items introduced multiple nutrient gaps. There were small new gaps for **calcium, zinc**, and the non-target nutrient **magnesium** when even one serving per week of any of the three items was included.

Seven servings per week of biscuits (24 grams a day) introduced the most additional nutrient gaps for this age group, including for **minerals, B vitamins, and choline**. Twenty-four grams is approximately five arrowroot biscuits, ten animal crackers, or two sandwich cookies. As in the pattern above with 17 servings of staple foods, in this scenario nearly all complementary foods were displaced (see results for food patterns, below).

It was not feasible for us to model all possible scenarios, but we note that combinations of these items consumed the same day would result in larger gaps for the youngest infants and could create new gaps for older IYC.

Table 21. Percent of nutrient reference values for problem nutrients when varying quantities of sentinel unhealthy items are included[a, b]

	Feasible best-case	1 serving SSB	3 servings SSB	7 servings SSB	1 serving biscuits	3 servings biscuits	7 servings biscuits	1 serving crisps/chips	3 servings crisps/chips	7 servings crisps/chips
6-8.9 mo, breastfed										
Target nutrients										
Calcium		95.5	86.8	83.9	91.8	84.6	68.6	95.8	87.8	85.5
Iron	27.8	27.4	26.5	21.6	27.5	23.5	10.6	27.6	27.3	22.8
Potassium				90.0		93.1	66.9			94.6
Zinc		97.4	92.4	62.1	95.6	76.9	41.8	98.0	93.3	63.9
Thiamin			96.5	92.8			80.5			97.9
Riboflavin							97.7			
Vitamin B6							58.6			
Choline							83.9			
Non-target nutrients										
Carbohydrate	73.3									
Copper							67.2			
Magnesium		96.1	92.2	82.8	96.1	86.0	65.7	96.8	96.3	90.9
Vitamin D	4.7	4.6	4.4	4.3	4.5	4.3	0.1	4.6	4.4	4.2
9-11.9 mo, breastfed										
Target nutrients										
Iron	41.1	40.3	38.7	34.8	40.1	37.8	30.5	40.8	40.1	38.3
Non-target nutrients										
Carbohydrate	91.4									
Vitamin D	4.5	4.5	4.6	5.9	4.5	4.5	4.7	4.5	4.5	4.5

	Feasible best-case	1 serving SSB	3 servings SSB	7 servings SSB	1 serving biscuits	3 servings biscuits	7 servings biscuits	1 serving crisps/chips	3 servings crisps/chips	7 servings crisps/chips
12-23.9 mo, breastfed										
Target nutrients										
Thiamin				96.0						
Non-target nutrients										
Carbohydrate	91.6									
Vitamin D	13.9	15.5	19.2	23.3	15.9	20.8	22.9	14.7	16.3	20.7
12-23.9 mo, non-breastfed										
Non-target nutrients										
Carbohydrate[c]	96.3									
Vitamin D[c]	2.6	2.6	2.6	5.1	2.6	2.6	4.6	2.6	2.5	2.7

[a] SSB = sugar-sweetened beverage. Nutrients are included if model results were less than 98% of an NRV for any of the scenarios. The feasible best-case scenario with all staple food subgroups allowed is shown for reference. Values at or above 98% are not shown.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

3a.5. Nutrient gaps when fortified items are included

Next, we explored the impact on nutrient gaps if one, three, or seven daily servings of selected fortified items were included. **Table 22** shows results, with the feasible best-case model results included for comparison.

For **breastfed infants 6-8.9 months of age**, compared to the feasible best-case food pattern, inclusion of MNPs:

- Substantially reduced the gap for **iron** and when included seven days a week, eliminated it;
- Substantially reduced the gap for **vitamin D;**
- When MNPs were included 7 days a week, there was a gap for the non-target nutrient **magnesium**.

For this same age group, inclusion of SQ-LNS:

- Substantially reduced the gap for **iron;**
- Substantially reduced the gap for **vitamin D;**
- When SQ-LNS was included 7 days a week, there were gaps for **potassium** and **choline**, and for the non-target nutrient **magnesium**.

Inclusion of Super Cereal Plus:

- Substantially reduced the gap for **vitamin D;**
- Increased the gap for **iron**, when included seven days a week.
- When Super Cereal Plus was included 3 days a week there were gaps for potassium and for the non-target nutrient **magnesium.**
- When it was included seven days a week previous mineral gaps were increased, and there were also gaps for **zinc, thiamin, choline**, and the non-target nutrient **copper**.

For **breastfed infants 9-11.9 months of age**:

- All three fortified items eliminated the gap for **carbohydrate** and substantially reduced the gap for **vitamin D.**
- MNPs and SQ-LNS substantially reduced the gap for **iron**, and MNPs eliminated the gap when included seven days a week. However, Super Cereal Plus did not reduce this gap.
- When MNPs were included seven days a week, there was a gap for the non-target nutrient **magnesium.**

For **breastfed infants 12-23.9 months of age**:

- All three fortified items eliminated the gap for **carbohydrate** and substantially reduced the gap for **vitamin D.**
- When MNPs or SQ-LNS were included three or seven days a week, there was a gap for the non-target nutrient **phosphorus.**
- When SQ-LNS was included seven days a week, there were gaps for **vitamin B12** and for **fiber**.

For **non-breastfed infants 12-23.9 months of age**:

- All three fortified items eliminated the gap for **carbohydrate** and substantially reduced the gap for **vitamin D.**
- There were no new gaps under any of the scenarios.

Table 22. Percent of nutrient reference values for problem nutrients when varying quantities of fortified items are included[a, b]

	Feasible best-case	1 serving MNP	3 servings MNP	7 servings MNP	1 serving SQ-LNS	3 servings SQ-LNS	7 servings SQ-LNS	1 serving SCP	3 servings SCP	7 servings SCP
6-8.9 mo, breastfed										
Target nutrients										
Iron	27.8	41.4	67.4		36.1	46.8	58.5	28.4	27.3	15.8
Potassium							75.5		95.0	55.5
Zinc										82.9
Thiamin										75.6
Choline							81.7			85.3
Non-target nutrients										
Carbohydrate	73.3									
Copper										71.9
Magnesium				77.0			97.3		94.6	87.6
Vitamin D	4.7	11.7	25.9	51.7	11.4	25.7	50.0	10.0	19.8	38.5
9-11.9 mo, breastfed										
Target nutrients										
Iron	41.1	54.1	80.1		48.5	61.6	85.0	41.6	41.7	38.4
Non-target nutrients										
Carbohydrate	91.4									
Magnesium				87.9						
Vitamin D	4.5	11.7	25.9	51.8	11.5	25.8	54.3	9.9	20.9	42.8

	Feasible best-case	1 serving MNP	3 servings MNP	7 servings MNP	1 serving SQ-LNS	3 servings SQ-LNS	7 servings SQ-LNS	1 serving SCP	3 servings SCP	7 servings SCP
12-23.9 mo, breastfed										
Target nutrients										
Vitamin B12							97.3			
Non-target nutrients										
Carbohydrate	91.6									
Fiber							79.7			
Phosphorus			83.9	73.4		82.4	75.4			
Vitamin D	13.9	8.9	23.3	51.9	11.6	22.2	50.7	23.2	39.2	71.9
12-23.9 mo, non-breastfed										
Non-target nutrients										
Carbohydrate	96.3									
Vitamin D	2.6	11.1	27.3	55.9	9.9	26.0	55.2	12.7	32.9	73.9

[a] Nutrients are included if model results were less than 98% of an NRV for any of the scenarios. The feasible best-case scenario with all staple food subgroups allowed is shown for reference. Values at or above 98% are not shown.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

In our sensitivity analyses for children 12-23.9 months of age we assumed 5% absorption of iron in scenarios with no flesh foods. For **breastfed children**, where the best-case scenario provided ~47% of the NRV for iron:

- Daily MNPs filled the iron gap.
- MNPs three days a week or SQ-LNS seven days a week substantially reduced the gap, to 78% and 86%, respectively.
- Super Cereal Plus did not reduce the iron gap.
- When MNPs were included seven days a week, there was a gap for the non-target nutrient phosphorus (83%).
- When SQ-LNS was included seven days a week, there was a gap for fiber (92%).
- Gaps for the non-target nutrient vitamin D were substantially reduced by all fortified items.

For **non-breastfed children 12-23.9 months of age**, where the best-case scenarios provided ~65% of the NRV for iron:

- Both daily MNPs and daily SQ-LNS filled the iron gap, while daily Super Cereal Plus slightly decreased the gap, but did not fill it (71% of NRV with daily Super Cereal Plus).
- When MNPs or SQ-LNS were included three days a week, they reduced the iron gap, yielding iron content of 96% and 84% of the NRV, respectively.
- When SQ-LNS was included seven days a week there was a gap for the non-target nutrient vitamin B12 (94%).
- Gaps for the non-target nutrient vitamin D were substantially reduced by all fortified items.

See Annex 10 for more details of these results.

3a.6. Scenarios where Tolerable Upper Intake Levels were exceeded

We assessed against the following ULs:

- 6-11.9 months: Calcium, iron, zinc and vitamin D
- 12-23.9 months: Calcium, copper, iron, phosphorus, zinc, vitamins B6, C, and D, and choline

We did not assess against the following ULs

- 6-11.9 months: Vitamin A, as the UL is for preformed vitamin A only and we could not distinguish forms in all food composition data
- 12-23.9 months: Vitamin A (as above); folic acid and niacin, because the ULs are for synthetic forms only; and magnesium, because the UL is for pharmacologic agents only

For all other target and non-target nutrients, there are no ULs for IYC (see Annex 2). Model solutions exceeded UL only for copper and zinc, as shown in **Table 23**. See Annex 9 for additional details. In sensitivity analyses assuming lower absorption of iron, the UL for zinc was exceed in around half of the scenarios that included fortified items, and the UL for copper was exceeded in almost all of the scenarios that included fortified items. See Annex 10 for details.

Table 23. Model solutions exceeding Tolerable Upper Intake Levels[a]

Scenarios	ULs	mg
6-8.9 mo, breastfed	Zinc, 5 mg	
7 servings MNP		5.3
3 servings SQ-LNS		5.2
7 servings SQ-LNS		8.9
9-11.9 mo, breastfed	Zinc, 5 mg	
High energy liberalized best-case		5.8
3 servings MNP		5.4
7 servings MNP		5.4
3 servings SQ-LNS		6.8
7 servings SQ-LNS		10.4
12-23.9 mo, breastfed	Zinc, 7 mg	
7 servings SQ-LNS		9.0
12-23.9 mo, non-breastfed	Zinc, 7 mg	
Scenario with no fruits or vegetables		7.6
7 servings SQ-LNS		10.0
12-23.9 mo, breastfed	Copper, 1 mg	
High energy feasible best-case		1.1
Middle energy liberalized best-case		1.2
Scenario with no whole grains		1.1
Staples restricted to roots/tubers		1.1
7 servings of MNP		1.1
12-23.9 mo, non-breastfed	Copper, 1 mg	
20 of 35 scenarios		>1 – 1.2

[a] MNP = multiple micronutrient powder; SQ-LNS = small-quantity lipid-based nutrient supplement; UL = Tolerable Upper Intake Level.

3b. Characteristics of food patterns

This section summarizes the following characteristics of the model solutions:

- Percent of energy intake from macronutrients
- Percent of energy intake from broad food groups
- Number of food groups and subgroups in model solutions
- Food subgroups selected
- Frequencies of consumption (number of daily servings)

Selected results are presented here, and more details are provided in Annex 9.

3b.1. Characteristics of feasible best-case food patterns and liberalized best-case food patterns

Macronutrient intakes as a percent of energy were relatively consistent across all feasible and liberalized best-case food patterns. The low energy food patterns had a higher percent of energy from protein (particularly for the oldest age group), and the liberalized food patterns tended to have a slightly higher percent of energy from protein and lower percent of energy from carbohydrates (see Annex 9 for details). **Table 24** shows the macronutrient ranges for each type of food pattern. For children 12-23.9 months of age, macronutrient distributions for all food patterns were within recommended ranges; recommended ranges are not set for infants.

Table 24. Percent of energy from macronutrients for best-case food patterns[a, b]

	Best-case food patterns			
	Feasible	**Liberal**	**AMDR[c]**	**RI[d]**
6-8.9 mo, breastfed				
Protein	13-14	14-15	-	-
Fat	43-45	43-45	-	-
Carbohydrate	43-46	41-44	-	-
9-11.9 mo, breastfed				
Protein	13-16	19-20	-	-
Fat	40	40	-	-
Carbohydrate	46-49	42-43	-	-
12-23.9 mo, breastfed				
Protein	11-20		5-20	-
Fat	35		30-40	35-40
Carbohydrate	48-59		45-65	45-60
12-23.9 mo, non-BF breastfed				
Protein	10-16		5-20	-
Fat	35-36		30-40	35-40
Carbohydrate	56-60		45-65	45-60

[a] Ranges are across low, middle, and high energy levels. Liberalized models for children 12-23.9 months were not run because there were no gaps in target nutrients in the feasible best-case model results.

[b] Note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%. They provide a general picture and can be compared across the food patterns, but amounts below or exceeding AMDR should be interpreted cautiously, unless the excess or deficit is large.

[c] AMDR = Acceptable Macronutrient Distribution Range. Source: National Academies of Sciences, Engineering, and Medicine (2019).

[d] RI = Reference Intake Range. Source: EFSA (European Food Safety Authority) (2017).

Table 25 shows the percent of energy from the broad food groups. Within the broad group 'protein foods', we also report the percent of energy from animal-source and plant-source foods.

Table 25. Percent of energy from food groups for best-case food patterns

	Low energy level[a]		Middle energy level[a]		High energy level[a]	
	Feasible	Liberal	Feasible	Liberal	Feasible	Liberal
6-8.9 mo breastfed						
Breastmilk	77	77	77	77	77	77
Starchy staples	5	5	4	4	4	4
Fruits	0	0	0	0	0	0
Vegetables	8	8	7	4	6	6
Dairy	0	0	3	0	0	0
Protein foods	9	10	9	15	14	14
Animal-source[b]	9	10	7	10	6	8
Plant-source[b]	0	0	2	5	8	6
Added fats and oils	0	0	0	0	0	0
9-11.9 mo breastfed						
Breastmilk	64	64	63	63	63	63
Starchy staples	5	5	9	4	13	3
Fruits	0	0	4	0	5	0
Vegetables	9	7	9	6	6	5
Dairy	4	0	1	0	0	0
Protein foods	18	25	15	27	13	28
Animal-source[b]	8	13	6	14	6	15
Plant-source[b]	10	12	8	12	7	13
Added fats and oils	0	0	0	0	0	0
12-23.9 mo breastfed						
Breastmilk	44		44		44	
Starchy Staples	10		26		24	
Fruits	3		10		16	
Vegetables	13		10		8	
Dairy	0		4		6	
Protein foods	30		7		2	
Animal-source[b]	14		6		1	
Plant-source[b]	16		1		1	
Added fats and oils	0		0		0	
12-23.9 mo non-breastfed						
Starchy staples	26		37		38	
Fruits	26		21		21	
Vegetables	13		10		7	
Dairy	18		15		12	
Protein foods	16		1		9	
Animal-source[b]	4		1		1	
Plant-source[b]	12		0		8	
Added fats and oils	2		16		13	

[a] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high

end of the age range and at the 75th percentile for weight-for-age. Liberalized models for children 12-23.9 months were not run because there were no gaps in target nutrients in the feasible best-case model results.

[b] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

The percent of energy from breast milk is fixed by design, within each age group.[19] The results in Table 25 suggest the following patterns for the main food groups:

- **Starchy staple foods**
  - Staples contributed only 4-5% of energy for the younger infants (6-8.9 months), corresponding to selection of the minimum of 3.5 daily servings per week of starchy staple foods.
  - Percent of energy from starchy staples tended to be higher with larger available kilocalories from complementary food.
  - For breastfed IYC 9-11.9 months, staples contributed a lower proportion of energy in the liberalized food patterns, where more generous amounts of other food groups could be selected.
- **Fruits**
  - There was no fruit in food patterns at 6-8.9 months of age and no fruit in the low energy level at 9-11.9 months.
  - At 9-11.9 months, fruit contributed 4-5% of energy in the feasible middle and high energy groups at 9-11.9 months, but not in the liberalized food patterns, where more generous amounts of other nutrient-dense food groups could be selected.
  - For breastfed children 12-23.9 months of age, fruit increased as a percent of energy as the energy level increased.
  - For non-breastfed children 12-23.9 months of age, the percent of energy from fruit was substantially higher than for the breastfed children, particularly at the low and middle energy levels.
- **Vegetables**
  - Unlike staples and fruits, the percent of energy from vegetables tended to go down as the energy level increased. This is because the same number of servings were selected at all levels, which was generally the maximum number allowed by model constraints.
  - Vegetables provided a slightly higher percent of energy for children 12-23.9 months of age, compared to infants; this may be because of larger serving sizes for the older IYC.
  - For children 12-23.9 months of age, the percent of energy from vegetables did not differ markedly between breastfed and non-breastfed children.
- **Dairy**
  - The percent of energy from dairy was zero (9 food patterns) or low (3 food patterns) for breastfed infants.
  - For breastfed children 12-23.9 months of age, the percent of energy from dairy increased with energy level but remained low at 0-6% of energy.
  - The percent of energy from dairy was highest for non-breastfed children but decreased as the energy level increased.
- **Protein foods**
  - In feasible best-case food patterns, the percent of energy from protein foods was higher in the high energy scenario for infants 6-8.9 months of age, whereas it decreased across energy levels for infants 9-11.9 months of age.

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[19] The slight variability in percent of energy from breast milk for infants 9-11.9 months of age reflects the fact that for technical reasons related to the software the minimum and maximum quantities per week must differ, so the minimum frequency for breast milk was set to 6.9999 days and the maximum to 7.0001 days a week.

    - For breastfed children 12-23.9 months of age, percent of energy from protein foods decreased markedly across energy levels; for non-breastfed children energy from protein foods was highest in the low energy level scenario. These results reflect that once all nutrient targets were met, Optifood minimized protein.
- **Added fats and oils**
    - There was no added fat or oil in the food patterns for breastfed IYC.
    - For non-breastfed children 12-23.9 months of age at the low energy intake level, energy from added fats/oils was low (2%); higher energy level food patterns had substantially more added fat/oil.

We provide similar results for percent of energy at the food subgroup level in Annex 9.

Table 26 compares percent of energy from macronutrients and from food groups from the sensitivity analyses exploring the impact of assuming 5%, rather than 10% absorption of iron, for children 12-23.9 months of age. The table shows results from above for the feasible best-case food patterns at the middle energy level assuming 10% absorption and compares these with results at 5% absorption.

For the lower absorption scenarios, there were small shifts in the percent of energy from macronutrients for breastfed children and more pronounced shifts for non-breastfed children, with increases in percent of energy from protein and decreases in carbohydrate, in both cases. All macronutrients were within AMDR.

The percent of energy from starchy staples decreased for breastfed but not for non-breastfed children. The percent of energy from fruits decreased for both groups. Vegetables remained the same, and there were only small shifts in dairy. There were large increases in the percent of energy from protein foods in both groups. For non-breastfed children, the percent of energy from added fats and oils decreased from 16% to zero.

The increases in protein foods and the decrease in added fats and oils both reflect that in the original analyses at 10% absorption, iron needs were met, and protein was then minimized. In the sensitivity analyses iron needs were not met, so Optifood selected more protein foods.

Table 26 Percent of energy from food groups under feasible best-case food patterns, with two levels of absorption of iron

	12-23.9 mo breastfed		12-23.9 mo non-breastfed	
Absorption of iron	10%	5%	10%	5%
Macronutrients[a]				
Protein	13.7	15.5	11.1	17.9
Fat	35.0	36.1	35.8	35.0
Carbohydrate	55.1	51.2	58.2	51.6
Food groups				
Breast milk	44.2	44.2	0	0.0
Starchy staples	25.5	15.9	37.4	35.7
Fruits	9.7	1.3	20.7	10.2
Vegetables	9.9	10.0	10.0	10.0
Dairy	3.7	7.8	14.9	12.7
Protein foods	7.0	20.8	1.2	31.5
Animal-source[b]	5.6	9.2	1.2	8.4
Plant-source[b]	1.4	11.7	0.0	23.1
Added fats and oils	0.0	0.0	15.9	0.0

[a] All percents of energy from macronutrients are within Acceptable Macronutrient Distribution Ranges. Note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%.

[b] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

Table 27 describes food group diversity of the food patterns in the model solutions for infants 6-8.9 months of age and **Table 28** shows the selected food subgroups and number of daily servings per week of each. **Tables 29-34** show the same results for older IYC. Across all age/feeding groups, several food groups and numerous food subgroups were selected at the maximum amount possible, as indicated in the tables.

Table 27. Food group and subgroup diversity in feasible and liberalized best-case food patterns for breastfed infants 6-8.9 months of age at three energy intake levels[a]

	Low energy level[b]		Middle energy level[b]		High energy level[b]	
	Feasible	**Liberal**	**Feasible**	**Liberal**	**Feasible**	**Liberal**
1. Starchy staple foods selected?[c]	Yes	Yes	Yes	Yes	Yes	Yes
# of subgroups selected, of 7	1	1	1	1	1	1
2. Fruits selected?	No	No	No	No	No	No
# of subgroups selected, of 7	0	0	0	0	0	0
3. Vegetables selected?	Yes	Yes	Yes	Yes	Yes	Yes
# of subgroups selected, of 6	5	4	5	2	5	3
4. Dairy selected?	No	No	Yes	No	No	No
# of subgroups selected, of 3	0	0	2	0	0	0
5. Protein foods selected?	Yes	Yes	Yes	Yes	Yes	Yes
# of animal-source subgroups selected, of 7	4	2	3	2	3	2
# of plant-source subgroups selected, of 3	0	0	1	1	2	1
Added fats and oils selected?	No	No	No	No	No	No
# of subgroups selected, of 2	0	0	0	0	0	0
Food group diversity						
Total number of subgroups, of 35[d]	10	7	12	6	11	7
Number of 5 main food groups[e]	3	3	4	3	3	3
Number of 8 IYCF indicator food groups[f]	5	5	7	6	6	6

[a] All model solutions included ~77% of energy from breast milk daily. IYCF = infant and young child feeding.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of the age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

[d] The 35 food subgroups are as defined in Table 6, and throughout this document.

[e] The 5 main food groups are: 1. starchy staple foods; 2. fruits; 3. vegetables; 4. dairy; and 5. protein foods.

[f] The 8 IYCF indicators food groups are: 1. breast milk; 2. grains, roots, tubers and plantains; 3. pulses (beans, peas, lentils), nuts and seeds; 4. dairy products (milk, infant formula, yogurt, cheese); 5. flesh foods (meat, fish, poultry, organ meats); 6. eggs; 7. vitamin-A rich fruits and vegetables; and 8. other fruits and vegetables. Minimum dietary diversity is defined as consuming foods and beverages from at least five out of eight defined food groups during the previous day (WHO 2021). Note that the modeled food patterns are weekly, and the indicator is based on a single day. Also, food groups were counted even when weekly quantities were small.

Table 28. Number of daily servings per week of food groups and subgroups in feasible and liberalized best-case food patterns for breastfed infants 6-8.9 months of age at three energy intake levels[a]

	Low energy level[b]		Middle energy level[b]		High energy level[b]	
	Feasible	Liberal	Feasible	Liberal	Feasible	Liberal
Breast milk[c]	7	7	7	7	7	7
Starchy staple foods[d]	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**	**3.5**
Whole grain breakfast cereals	3.5	3.5	3.5	3.5	3.5	3.5
Vegetables	24.5	25.1	24.5	10.1	24.5	21
Dark green leafy vegetables	4	7	4	7	4	7
Other brassicas	6	7	6	0	3.9	0
Peppers and tomatoes	6	7	3.9	0	6	7
Peas and beans (immature seeds/pods)	4	4.1	4	3.1	4	7
Other vegetables	4.5	0	6.6	0	6.6	0
Dairy	0	0	2.3	0	0	0
Milk	0	0	1.3	0	0	0
Cheese	0	0	1	0	0	0
Protein foods	8.3	11.3	10	21	14	21.9
Legumes	0	0	0	0	4	0.9
Soy foods	0	0	2	7	2	7
Beef, lamb, goat, game	1.7	0	3	0	3	0
Pork	1.6	0	0	0	0	0
Liver	2	7	2	7	2	7
Small fish	3	4.3	3	7	3	7

[a] Table lists only those food groups and subgroups that were selected in at least one of the six model solutions. Values at the minimum possible level are bolded, and values at the maximum possible level are shaded. Group and subgroup level maxima for feasible best-case models are as defined in Table 10. Maxima for liberalized best-case models are 7 daily servings per week at the subgroup level, and this is multiplied by the number of subgroups to yield a weekly food group level maximum.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required 7 daily servings of breast milk, providing ~77% of energy.

[d] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

Table 29. Food group and subgroup diversity in feasible and liberalized best-case food patterns for breastfed infants 9-11.9 months of age at three energy intake levels[a]

	Low energy level[b]		Middle energy level[b]		High energy level[b]	
	Feasible	Liberal	Feasible	Liberal	Feasible	Liberal
Starchy staple foods selected?[c]	Yes	Yes	Yes	Yes	Yes	Yes
# of subgroups selected, of 7	1	1	2	1	2	1
Fruits selected?	Yes	No	Yes	No	Yes	No
# of subgroups selected, of 7	1	0	2	0	2	0
Vegetables selected?	Yes	Yes	Yes	Yes	Yes	Yes
# of subgroups selected, of 6	5	3	5	3	5	3
Dairy	Yes	No	Yes	No	No	No
# of subgroups selected, of 3	2	0	1	0	0	0
Protein foods	Yes	Yes	Yes	Yes	Yes	Yes
# of animal-source subgroups selected, of 7	3	3	3	3	3	4
# of plant-source subgroups selected, of 3	2	2	2	2	2	2
Added fats and oils selected?	No	No	No	No	No	No
# of subgroups selected, of 2	0	0	0	0	0	0
Food group diversity						
Total number of subgroups, of 35[d]	14	9	15	9	14	10
Number of five main food groups[e]	5	3	5	3	4	3
Number of eight IYCF indicators food groups[f]	7	6	7	6	6	7

[a] All model solutions also included ~63-64% of energy from breast milk daily. IYCF = infant and young child feeding.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of the age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

[d] The 35 food subgroups are as defined in Table 6, and throughout this document.

[e] The 5 main food groups are: 1. starchy staple foods; 2. fruits; 3. vegetables; 4. dairy; and 5. protein foods.

[f] The 8 IYCF indicators food groups are: 1. breast milk; 2. grains, roots, tubers and plantains; 3. pulses (beans, peas, lentils), nuts and seeds; 4. dairy products (milk, infant formula, yogurt, cheese); 5. flesh foods (meat, fish, poultry, organ meats); 6. eggs; 7. vitamin-A rich fruits and vegetables; and 8. other fruits and vegetables. Minimum dietary diversity is defined as consuming foods and beverages from at least five out of eight defined food groups during the previous day (WHO 2021). Note that the modeled food patterns are weekly, and the indicator is based on a single day. Also, food groups were counted even when weekly quantities were small.

Table 30. Number of daily servings per week of food groups and subgroups in feasible and liberalized best-case food patterns for breastfed infants 9-11.9 months of age at three energy intake levels[a]

	Low energy level[b]		Middle energy level[b]		High energy level[b]	
	Feasible	Liberal	Feasible	Liberal	Feasible	Liberal
Breast milk[c]	7	7	7	7	7	7
Starchy staple foods[d]	**3.5**	**3.5**	7.4	**3.5**	12	**3.5**
Whole grain breakfast cereals	3.5	3.5	6	3.5	6	3.5
Whole grain bakery products	0	0	1.4	0	6	0
Fruits	2	0	3.2	0	3.9	0
Berries	2	0	2	0	2	0
High-fat fruits	0	0	1.2	0	1.9	0
Vegetables	24.5	21	24.5	21	24.5	21
Dark green leafy vegetables	4	7	4	7	4	7
Other brassicas	5.7	0	2.5	0	0	0
Vitamin A-rich orange vegetables	3.8	0	7	0	3.8	0
Peppers and tomatoes	0	7	0	7	5.7	7
Peas and beans (immature seeds/pods)	4	7	4	7	4	7
Other vegetables	7	0	7	0	7	0
Dairy	2.4	0	0.7	0	0	0
Milk	0.3	0	0	0	0	0
Cheese	2.1	0	0.7	0	0	0
Protein foods	14	25.6	14	30.4	14	34.9
Eggs	0	0	0	0	0	0.6
Legumes	4	2.9	4	4.4	4	6.3
Soy foods	2	7	2	7	2	7
Beef, lamb, goat, game	3	1.7	3	5	3	7
Liver	2	7	2	7	2	7
Small fish	3	7	3	7	3	7

[a] Table lists only those food groups and subgroups that were selected in at least one of the six model solutions. Values at the minimum possible level are bolded, and values at the maximum possible level are shaded. Group and subgroup level maxima for feasible models are as defined in Table 10. Maxima for liberal models are 7 daily servings per week at the subgroup level, and this is multiplied by the number of subgroups to yield a weekly food group level maximum.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required 7 daily servings of breast milk, providing ~63-64% of energy.

[d] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

Table 31. Food group and subgroup diversity in feasible best-case food patterns for breastfed children 12-23.9 months of age at three energy intake levels[a]

	Low energy level[b]	Middle energy level[b]	High energy level[b]
Starchy staple foods selected?[c]	Yes	Yes	Yes
Number of subgroups selected, of 7	1	3	4
Fruits selected?	Yes	Yes	Yes
Number of subgroups selected, of 7	1	3	4
Vegetables selected?	Yes	Yes	Yes
Number of subgroups selected, of 6	6	5	5
Dairy selected?	No	Yes	Yes
Number of subgroups selected, of 3	0	1	1
Protein foods selected?	Yes	Yes	Yes
Number of animal-source subgroups selected, of 7	3	2	1
Number of plant-source subgroups selected, of 3	3	1	1
Added fats and oils selected?	No	No	No
# of subgroups selected, of 2	0	0	0
Food group diversity			
Total number of subgroups, of 35[d]	14	15	16
Number of 5 main food groups[e]	4	5	5
Number of 8 IYCF food groups[f]	6	7	7

[a] All model solutions also included ~44% of energy from breast milk daily. IYCF = infant and young child feeding.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of the age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

[d] The 35 food subgroups are as defined in Table 6, and throughout this document.

[e] The 5 main food groups are: 1. starchy staple foods; 2. fruits; 3. vegetables; 4. dairy; and 5. protein foods.

[f] The 8 IYCF indicators food groups are: 1. breast milk; 2. grains, roots, tubers and plantains; 3. pulses (beans, peas, lentils), nuts and seeds; 4. dairy products (milk, infant formula, yogurt, cheese); 5. flesh foods (meat, fish, poultry, organ meats); 6. eggs; 7. vitamin-A rich fruits and vegetables; and 8. other fruits and vegetables. Minimum dietary diversity is defined as consuming foods and beverages from at least five out of eight defined food groups during the previous day (WHO 2021). Note that the modeled food patterns are weekly, and the indicator is based on a single day. Also, food groups were counted even when weekly quantities were small.

Table 32. Number of daily servings per week of food groups and subgroups in feasible best-case food patterns for breastfed children 12-23.9 months of age at three energy intake levels[a]

	Low energy level[b]	Middle energy level[b]	High energy level[b]
Human milk[c]	7	7	7
Starchy staple foods[d]	6	14.5	16.7
Whole grains	0	1.5	2.2
Whole grain breakfast cereals	6	6	6
Whole grain bakery products	0	7	7
Starchy roots, tubers, plantains	0	0	1.5
Fruits	2.7	7.7	17.5
Vitamin A-rich fruits	0	2.2	4
Berries	0	3	3
Citrus	2.7	0	0
High-fat fruits	0	2.5	4
Other fruits	0	0	6.5
Vegetables	28	28	28
Dark green leafy vegetables	7	7	7
Other brassicas	6	3	3
Vitamin A-rich orange vegetables	7	7	7
Peppers and tomatoes	3.3	0	0
Peas and beans (immature seeds/pods)	4	4	4
Other vegetables	0.7	7	7
Dairy	0	1.4	2.6
Milk	0	1.4	2.6
Protein foods	17.5	8	5
Legumes	3.9	0	0
Soy foods	3	3	3
Nuts and seeds	2.2	0	0
Beef, lamb, goat, game	1	0	0
Liver	2	2	2
Small fish	5.4	3	0

[a] Table lists only those food groups and subgroups that were selected in at least one of the three model solutions. Values at the minimum possible level are bolded, and values at the maximum possible level are shaded. Group and subgroup level maxima for feasible models are as defined in Table 10. Maxima for liberal models are 7 daily servings per week at the subgroup level, and this is multiplied by the number of subgroups to yield a weekly food group level maximum.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

[c] All model solutions required 7 daily servings of breast milk, providing ~44% of energy.

[d] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

Table 33. Food group and subgroup diversity in feasible best-case food patterns for non-breastfed children 12-23.9 months of age at 3 energy intake levels[a]

	Low energy level[b]	Middle energy level[b]	High energy level[b]
Starchy staple foods selected?[b]	Yes	Yes	Yes
Number of subgroups selected, of 7	2	4	5
Fruits selected?	Yes	Yes	Yes
Number of subgroups selected, of 7	4	5	4
Vegetables selected?	Yes	Yes	Yes
Number of subgroups selected, of 6	5	5	5
Dairy selected?	Yes	Yes	Yes
Number of subgroups selected, of 3	1	1	1
Protein foods selected?	Yes	Yes	Yes
Number of animal-source subgroups selected, of 7	3	1	2
Number of plant-source subgroups selected, of 3	2	0	1
Added fats and oils selected?	Yes	Yes	Yes
# of subgroups selected, of 2	1	2	2
Food group diversity			
Total number of subgroups, of 35[c]	18	18	20
Number of 5 main food groups[d]	5	5	5
Number of 8 IYCF food groups[e]	7	5	7

[a] Low energy levels are the estimated energy requirement (EER) of girls at the low end of the age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age. IYCF = infant and young child feeding.

[b] All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

[c] The 35 food subgroups are as defined in Table 6, and throughout this document.

[d] The 5 main food groups are: 1. starchy staple foods; 2. fruits; 3. vegetables; 4. dairy; and 5. protein foods.

[e] The 8 IYCF indicators food groups are: 1. breast milk; 2. grains, roots, tubers and plantains; 3. pulses (beans, peas, lentils), nuts and seeds; 4. dairy products (milk, infant formula, yogurt, cheese); 5. flesh foods (meat, fish, poultry, organ meats); 6. eggs; 7. vitamin-A rich fruits and vegetables; and 8. other fruits and vegetables. Minimum dietary diversity is defined as consuming foods and beverages from at least five out of eight defined food groups during the previous day (WHO 2021). Note that the modeled food patterns are weekly, and the indicator is based on a single day. Also, food groups were counted even when weekly quantities were small.

Table 34. Number of daily servings per week of food groups and subgroups in feasible best-case food patterns for non-breastfed children 12-23.9 months of age at three energy intake levels[a]

	Low energy level[b]	Middle energy level[b]	High energy level[b]
Starchy staple foods	13	21	19.4
Whole grains	0	3.1	7
Refined grains	0	0	1.7
Whole grain breakfast cereals	6	5.5	0
Refined grain breakfast cereals	0	0	1.4
Whole grain bakery products	7	6.1	2.3
Starchy roots, tubers, plantains	0	6.3	7
Fruits	15.7	17.5	17.5
Vitamin A-rich fruits	4	4	4
Berries	3	3	0
Citrus	0	3.1	0
Bananas	0	0	7
High-fat fruits	4	4	4
Other fruits	4.7	3.4	2.5
Vegetables	28	28	28
Dark green leafy vegetables	7	7	7
Other brassicas	6	6	6
Vitamin A-rich orange vegetables	7	7	7
Peppers and tomatoes	0	0	1
Peas and beans (immature seeds/pods)	4	4	0
Other vegetables	4	4	7
Dairy	2.5	2.8	2.9
Milk	2.5	2.8	2.9
Protein foods	10.1	2	6.1
Eggs	0.3	0	0.5
Soy foods	3	0	0
Nuts and seeds	4	0	5.5
Liver	2	2	0.1
Small fish	0.8	0	0
Added fats and oils	0.8	14	14
Solid fats and saturated oils	0	7	7
Other vegetable oils	0.8	7	7

[a] Table lists only those food groups and subgroups that were selected in at least one of the three model solutions. Values at the minimum possible level are bolded, and values at the maximum possible level are shaded. Group and subgroup level maxima for feasible models are as defined in Table 10. Maxima for liberal models are 7 daily servings per week at the subgroup level, and this is multiplied by the number of subgroups to yield a weekly food group level maximum. All model solutions required a minimum of 3.5 daily servings of starchy staple foods per week; minima for all other food groups are zero.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. High energy levels are the EER of boys at the high end of the age range and at the 75th percentile for weight-for-age.

Breastfed infants 6-8.9 months (Tables 27-28)
All models used constraints to ensure the solutions included a fixed percent of energy from breast milk per day and a minimum of 3.5 daily servings of starchy staple foods per week. For all six models, Optifood selected the minimum quantity of staple foods per week, and within the food group the only subgroup selected was whole grain breakfast cereals.

Among the other food groups, we observed:

- Neither fruits nor added fats and oils were selected for this age group, and dairy was selected in only one of six model solutions.
- All model solutions included vegetables and animal-source protein foods, and there was diversity in selection of food subgroups within these two groups. A majority of the models also included plant-source protein foods.
- The feasible best-case food patterns included the weekly food group level maximum for vegetables, at all three energy levels.
- The feasible best-case food pattern at the high energy level included the weekly food-group level maximum for protein foods.

Regarding food subgroups:

- Across the six model solutions, the following food subgroups were selected at the maximum level:
    - Dark green leafy vegetables, and liver (all six solutions)
    - Small fish eaten with bones (five solutions)
    - Peppers/tomatoes, immature peas/beans, and soy foods (four solutions)
    - Other brassicas (non-leafy) (three solutions)
    - Beef/lamb/goat/game (two solutions)
    - Legumes (one solution)

Diversity:

- Diversity of subgroups was lower in the liberalized models where larger amounts of each subgroup could be selected.
- Considering the five main food groups in our modeling scheme, most solutions included three of five.
- Model solutions included from five to seven of the eight IYCF indicators food groups.

Breastfed infants 9-11.9 months (Tables 29-30)
As for the younger infants, model constraints ensured that solutions included a fixed percent of energy from breast milk per day and a minimum of 3.5 daily servings of starchy staple foods per week.

Regarding food groups:

- The low energy level for the feasible best-case scenario as well as all three liberalized scenarios included the minimum possible number of daily servings of staple foods. The middle and high energy feasible food patterns included more. Among the seven starchy staple food subgroups, only whole grain breakfast cereals and whole grain bakery products were selected.
- Added fats and oils were not selected in any food patterns.
- Dairy products were selected in only two of six food patterns, in limited amounts (0.7-2.4 daily servings/week).
- Fruits were selected in all three feasible food patterns but in none of the liberalized food patterns. When other food groups were available to select in larger quantities (vegetables, protein foods) fruits were not selected.
- In feasible best-case food patterns at all three energy levels, the solutions included the weekly food group level maxima for vegetables and for protein foods.

Regarding food subgroups:

- All six solutions included numerous vegetable and protein food subgroups, and all included both animal-source and plant-source protein foods.
- Across the six model solutions, the following food subgroups were selected at the maximum level:
    - Dark green leafy vegetables, immature peas/beans, soy foods, liver, and small fish eaten with bones (all six solutions)
    - Beef/lamb/goat/game (four solutions)
    - Berries, peppers/tomatoes, other vegetables, and legumes (three solutions)
    - Whole grain breakfast cereals (two solutions)
    - Whole grain bakery products and vitamin A-rich orange vegetables (one solution)

Diversity:

- As was the case for younger infants, diversity of subgroups was lower in the liberalized models where larger amounts of each subgroup could be selected.
- The feasible food pattern solutions included four or five of the five main food groups in our modeling scheme, while the liberalized food pattern solutions included three groups.
- Model solutions included six or seven of the eight IYCF indicators food groups.

Breastfed children 12-23.9 months (Tables 31-32)

As for the infants, model constraints ensured that all solutions included a fixed percent of energy from breast milk per day and a minimum of 3.5 daily servings of starchy staple foods per week. Unlike for the infants, model solutions had no gap in target nutrients so liberalized models were not run for this group. As noted, once all nutrient targets are met the Optifood software minimizes protein. This is reflected in results for this age group.

Regarding food groups:

- Food patterns for this age group included more servings of staple foods, and the number of servings increased across the energy intake levels. Staple foods included only whole grain subgroups (all energy levels) as well as a small amount of roots/tubers/plantains at the higher energy level only.
- Added fats and oils were not selected in any food pattern.
- Dairy products were selected in two of three food patterns, and in limited amounts (1.4-2.6 daily servings per week).
- Fruits were selected in all three feasible food patterns and increased across the energy intake levels. The high energy level solution included the weekly food group level maximum for fruit.
- All three feasible food patterns included the weekly food group level maximum for vegetables.
- For protein foods, diversity of subgroups and the total number of daily servings decreased across the energy intake levels. This was likely because at higher energy levels nutrient needs were met with larger quantities of less protein-dense foods, and/or because of the secondary Optifood objective of minimizing protein, once target nutrient needs were met.

Regarding food subgroups:

- Across the three model solutions, the following food subgroups were selected at the maximum level:
    - Whole grain breakfast cereals, dark green leafy vegetables, vitamin A-rich orange vegetables, immature peas/beans, soy foods, and liver (all three energy levels)
    - Whole grain bakery products, berries, and other vegetables (two energy levels)
    - High-fat fruit (high energy level only)

Diversity:

- All three food patterns included numerous vegetable and protein food subgroups, all except the low energy solution included diverse fruits, and all included both animal-source and plant-source protein foods.
- The food patterns included four or five of the five main food groups in our modeling scheme.
- The food patterns included six or seven of the eight IYCF indicators food groups.

Non-breastfed children 12-23.9 months (Tables 33-34)

Model constraints ensured that all solutions included a minimum of 3.5 daily servings of starchy staple foods per week. Model solutions had no gap in target nutrients, so liberalized models were not run for this group. Once all nutrient targets are met the Optifood software minimizes protein, and this is reflected in results.

For food groups, we observed:

- Food patterns for this group included 13-21 daily servings of staple foods. The high energy intake level for this group was the only food pattern we modeled where refined grain foods were selected (two subgroups, total of 3.1 daily servings per week).
- Model solutions included the food group level maxima for the following:
    - Vegetables (all energy intake levels)
    - Fruits, and added fats and oils (middle and high energy intake levels)
    - Staple foods (middle energy intake level)
- Fluid milk was selected at all energy intake levels (2.5-2.9 475-gram daily servings, or about 5-6 cups per week).
- The number of servings of protein foods, and the variety in subgroups, was highest in the low energy level scenario. Protein foods were particularly low in the middle energy level solution, at two 20-gram servings per week of liver. The low level of protein foods in this solution reflects the Optifood secondary objective of reducing protein.
- This age/feeding group was the only one modeled where nuts/seeds were included in model solutions (two of three scenarios).
- Unlike for breastfed IYC, added fats and oils were included in all model solutions for non-breastfed children.

Regarding food subgroups:

- Across the three model solutions, the following food subgroups were selected at the maximum level:
    - Vitamin A-rich fruit, high-fat fruit, dark green leafy vegetables, other brassicas (non-leafy), and vitamin A-rich orange vegetables (all three energy levels)
    - Berries, immatures peas/beans, and liver (two energy levels)
    - Whole grains, whole grain breakfast cereals, whole grain bakery products, roots/tubers/plantains, bananas, other vegetables, and soy foods (one energy level)

Diversity:

- Solutions at all three energy levels had high diversity in fruits and vegetables and in total food subgroups (18-20 subgroups).
- The model solutions included all five of the five main food groups in our modeling scheme.
- Model solutions included five to seven of the eight IYCF indicators food groups.

See Annex 10 for details of food subgroup diversity and servings for the sensitivity analyses under the assumption of lower absorption of iron, for children 12-23.9 months of age. In general, these follow the pattern noted above for percent of energy from food groups, with notably fewer servings of fruits and more servings of protein foods.

In these lower-absorption scenarios, where flesh foods were excluded, eggs, legumes, and soy foods were included at or near the maximum amounts allowed for both feeding groups. For non-breastfed children nuts/seeds also approached the maximum amount allowed.

3b.2. Characteristics of food patterns when eliminating selected food subgroups and groups

Eliminating food groups or subgroups had little impact on macronutrient profiles for infants. For children 12-23.9 months of age, there were also few impacts. Changes of five or more percentage points, when comparing to all food groups, are summarized in **Table 35.** The largest differences were seen when both fruits and vegetables were eliminated, leading to higher intakes of protein and lower intakes of carbohydrate.

Table 35. Differences in percent of energy from macronutrients when food groups or subgroups are eliminated[a, b, c]

	All food groups	No whole grain	No vegetables	No fruits or vegetables	No legumes nuts seeds	No dairy	No liver or small fish
12-23.9 mo, breastfed							
Protein	13.7	15.0	20.3	21.6	13.7		18.5
Fat	35.0	40.1	35.0	35.0	30.1		37.2
Carbohydrate	55.1	49.1	46.5	44.7	60.1		46.7
12-23.9 mo, non-breastfed							
Protein	11.1	12.9		24.8		14.9	
Fat	35.8	42.3		35.0		40.7	
Carbohydrate	58.2	49.3		41.2		50.1	

[a] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[b] Scenarios with no large differences from the 'all food groups' scenario are omitted.

[c] Shaded cells indicate values that fall below or exceed Acceptable Macronutrient Distribution Ranges (AMDR) of: protein, 5-20%; fat, 30-40%; carbohydrate, 45-65% (National Academies of Sciences, Engineering, and Medicine 2019). However, note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%. They provide a general picture and can be compared across the food patterns, but amounts below or exceeding AMDR should be interpreted cautiously, unless the excess or deficit is large.

Table 36 shows the percent of energy from the broad food groups when food groups or subgroups were eliminated. We provide similar results for percent of energy at the food subgroup level in Annex 9.

Table 36. Percent of energy from food groups when food groups or subgroups are eliminated[a]

	All food groups	No whole grain	No vegetables	No fruits	No fruits or vegetables	No legumes nuts seeds	No dairy	No eggs	No liver or small fish	No meat poultry fish	No meat poultry fish eggs
6-8.9 mo breastfed											
Breastmilk	77	77	77	77	77	77	77	77	77	77	77
Starchy staples	4	5	5	4	5	4	4	4	4	4	4
Fruits	0	0	0	0	0	0	0	0	0	0	0
Vegetables	7	5	0	7	0	7	8	7	8	7	7
Dairy	3	4	6	3	6	3	0	3	5	5	5
Protein foods	9	9	12	9	12	7	10	9	6	6	7
Animal-source[b]	7	8	11	7	11	7	8	7	4	1	0
Plant-source[b]	2	2	2	2	2	0	2	2	2	6	7
Added fats and oils	0	0	0	0	0	0	0	0	0	0	0
9-11.9 mo breastfed											
Breastmilk	63	64	63	64	63	64	63	63	63	63	64
Starchy staples	9	4	15	11	16	13	9	9	7	9	12
Fruits	4	8	1	0	0	0	4	4	0	0	0
Vegetables	9	9	0	7	0	9	9	9	9	6	7
Dairy	1	1	5	2	6	1	0	1	2	6	8
Protein foods	15	15	15	15	15	14	15	15	18	16	8
Animal-source[b]	6	6	6	7	6	14	7	6	10	7	0
Plant-source[b]	8	8	8	8	8	0	8	8	8	8	8
Added fats and oils	0	0	0	2	0	0	0	0	0	0	0

	All food groups	No whole grain	No vegetables	No fruits	No fruits or vegetables	No legumes nuts seeds	No dairy	No eggs	No liver or small fish	No meat poultry fish	No meat poultry fish eggs
12-23.9 mo breastfed											
Breastmilk	44	44	44	44	44	44	44	44	44	44	44
Starchy staples	26	4	17	35	20	29	24	29	9	16	21
Fruits	10	21	5	0	0	8	14	6	1	1	1
Vegetables	10	10	0	10	0	10	10	10	10	10	10
Dairy	4	0	5	3	6	3	0	5	8	8	12
Protein foods	7	21	28	7	30	6	8	6	27	21	12
Animal-source[b]	6	10	17	6	20	6	8	5	16	9	0
Plant-source[b]	1	11	11	1	10	0	0	1	12	12	12
Added fats and oils	0	0	0	0	0	0	0	0	0	0	0
12-23.9 mo non-breastfed											
Starchy staples	37	16	35	49	25	37	30	37	38	38	28
Fruits	21	21	21	0	0	21	21	21	21	21	21
Vegetables	10	10	0	9	0	10	10	10	10	10	10
Dairy	15	15	13	16	41	15	0	15	15	15	18
Protein foods	1	23	18	9	31	1	23	1	3	3	9
Animal-source[b]	1	2	7	2	17	1	11	1	1	1	0
Plant-source[b]	0	21	10	8	14	0	13	0	1	1	9
Added fats and oils	16	16	13	16	3	16	16	16	13	13	14

[a] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[b] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

The percent of energy from breast milk is fixed by design, within each age group,[20] declining from 77% of energy for infants 6-8.9 months of age to 44% of energy for breastfed children 12-23.9 months of age. Accordingly, the absolute size of shifts in percent energy from food groups was lowest for the younger infants and highest for the non-breastfed children.

Breastfed infants 6-8.9 months

We observed the largest shifts when vegetables were eliminated and when various subsets of flesh foods (meat, liver, poultry and fish) were eliminated. Eliminating vegetables led to increases in dairy and protein foods, presumably to meet iron and other mineral needs. Eliminating flesh foods (various combinations of subgroups) led to increases in dairy and plant-source protein foods. Staple foods remained at the stipulated minimum number of daily servings per week, in all scenarios.

Breastfed infants 9-11.9 months

For the older infants, eliminating whole grain staple foods led to a reduction in starchy staple foods to the stipulated minimum, and to an increase in fruits. Eliminating vegetables led to increases in dairy and starchy staple foods; examination of food subgroups (Annex 9) confirms the increase was in whole grain foods. Elimination of legumes, nuts and seeds also led to increases in whole grain staple foods, as well as in animal-source protein foods. Elimination of liver and small fish led to an increase in other animal-source protein foods, and broader elimination of flesh foods (various combinations of subgroups) led to an increase in dairy.

Breastfed children 12-23.9 months

When all staple food subgroups were included, the model solution for breastfed children 12-23.9 months of age included 26% of energy from starchy staples. When whole grain foods were eliminated, energy from starchy staples was reduced to the minimum amount allowed (i.e., 3.5 servings per week, which provided 4% of total energy), and the percent of energy from protein foods was tripled, with increases in both animal- and plant-source protein foods. This is an important point to note because there are many contexts where whole grain consumption does not comprise the majority of starchy staple consumption.

When vegetables were eliminated, starchy staples were reduced to a lesser extent, and again both types of protein foods were substantially increased. Conversely, when fruits were eliminated, starchy staple foods were increased; examination of subgroups (Annex 9) showed this increase was in the white roots/tubers/plantains subgroup. When both fruits and vegetables were eliminated, there were large increases in both animal- and plant-source protein foods.

When liver and small fish were eliminated, starchy staple foods were reduced from 29% to 9% of energy and dairy, animal-source protein foods, and plant-source protein foods were all substantially increased. This is also an important point to note, because liver and small fish were very rarely consumed in most contexts for which we had data.

Non-breastfed children 12-23.9 months

When all staple food subgroups were included, the model solution for breastfed children 12-23.9 months of age included 37% of energy from starchy staples. When whole grain foods were eliminated, energy from starchy staples was reduced to 16%, and plant-source protein foods were increased from 0 to 21% of energy.

[20] The slight variability in percent of energy from breast milk for infants 9-11.9 months of age reflects the fact that for technical reasons related to the software the minimum and maximum quantities per week must differ, so the minimum frequency for breast milk was set to 6.9999 days and the maximum to 7.0001 days a week.

When vegetables were eliminated, both animal- and plant-source protein foods were increased and when fruits were eliminated, starchy staples and plant-source protein foods were increased. When both fruits and vegetables were eliminated, there was a very large increase in percent of energy from dairy, and both animal- and plant-source protein foods were also substantially increased.

When dairy was eliminated, starchy staples were slightly reduced and both animal- and plant-source protein foods were increased substantially. Elimination of flesh foods had little impact on patterns, but elimination of both flesh foods and eggs led to a reduction in staple foods, a small increase in dairy, and an increase from 0 to 9% of energy from plant-source protein foods.

Food group and subgroup diversity

For most scenarios food group and subgroup diversity were generally similar to the models with all food groups, because when one food group or subgroup was eliminated, others were selected. The largest impact on food group and subgroup diversity occurred when all fruits or vegetables were eliminated, followed by scenarios when vegetables alone or various flesh foods were eliminated (see Annex 9).

3b.3. Characteristics of food patterns when staple foods are limited in variety or increased in quantity

Restricting staple foods to a single type had little impact on macronutrient profiles. **Table 37** summarizes changes of five or more percentage points, when comparing to models where all staple subgroups were allowed. For breastfed children 12-23.9 months of age, the model allowing only the roots/tubers/plantains subgroup resulted in higher fat and lower carbohydrate; results were similar in the rice only scenario for non-breastfed IYC.

Table 37. Percent of energy from macronutrients when staples are monotonous[a, b, c]

	All staples	Only roots tubers plantains	Only whole-grain white maize	Only refined white rice
12-23.9 mo, breastfed				
Protein	13.7	15.0		
Fat	35.0	40.1		
Carbohydrate	55.1	49.1		
12-23.9 mo, non-breastfed				
Protein	11.1			13.2
Fat	35.8			42.3
Carbohydrate	58.2			48.6

[a] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[b] Results are shown only for scenarios where percent of energy differed from the reference pattern by at least five percentage points. There were no differences of this size in scenarios for infants.

[c] Shaded cells indicate values that fall below or exceed Acceptable Macronutrient Distribution Ranges (AMDR) of: protein, 5-20%; fat, 30-40%; carbohydrate, 45-65% (National Academies of Sciences, Engineering, and Medicine 2019). However, note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%. They provide a general picture and can be compared across the food patterns, but amounts below or exceeding AMDR should be interpreted cautiously, unless the excess or deficit is large.

We also explored the impact of larger amounts of staple foods for breastfed IYC (all age groups) but did not do so for non-breastfed IYC because the model solution already included the maximum allowed number of daily servings of starchy staple foods (21 daily servings; that is, daily servings of 3 diverse staple food subgroups).

Impacts were marked only in the youngest age group, where increasing the minimum servings of staple foods to 17 daily servings per week increased the percent of energy from carbohydrate and decreased both protein and fat, as shown in **Table 38**.

Table 38. Percent of energy from macronutrients when staples are increased in quantity[a, b]

	Minimum number of staple food daily servings per week				
6-8.9 mo, breastfed	0 minimum	Best-case (3.5 staples)	7 minimum	14 minimum	17 minimum
Protein	14.3	13.6	13.1	9.0	8.1
Fat	44.5	44.8	43.3	40.6	40.2
Carbohydrate	42.9	43.3	45.3	52.1	53.0
9-11.9 mo, breastfed			Best-case (7.4 staples)	14 minimum	21 minimum
Protein			14.2	14.1	11.7
Fat			40.0	40.0	38.6
Carbohydrate			48.0	48.0	51.5
12-23.9 mo, breastfed				Best-case (14.5 staples)	21 minimum
Protein				13.7	14.2
Fat				35.0	35.1
Carbohydrate				55.1	53.9

[a] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. The shaded cells show results from the feasible best-case scenario, for reference.

[b] Note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%.

The results for macronutrients were consistent with shifts in the percent of energy from the various food groups, as shown in **Tables 39-40**. Patterns of displacement were not consistent across age/feeding groups; impacts were larger in absolute terms for older IYC because of the larger percent of energy available for complementary foods and beverages.

Table 39. Percent of energy from food groups when staple foods are monotonous[a]

	All staples	Only roots tubers plantains	Only whole-grain white maize	Only refined white rice
6-8.9 mo breastfed				
Breastmilk	77	77	77	77
Starchy Staples	4	4	10	10
Fruits	0	0	0	0
Vegetables	7	5	6	6
Dairy	3	4	0	0
Protein foods	9	10	7	7
Animal-source	7	9	7	7
Plant-source	2	2	0	0
Added fats and oils	0	0	0	0
9-11.9 mo breastfed				
Breastmilk	63	64	63	63
Starchy Staples	9	4	9	9
Fruits	4	8	3	4
Vegetables	9	9	8	7
Dairy	1	1	2	2
Protein foods	15	15	15	15
Animal-source	6	6	6	6
Plant-source	8	8	8	8
Added fats and oils	0	0	0	0
12-23.9 mo breastfed				
Breastmilk	44	44	44	44
Starchy Staples	26	4	26	14
Fruits	10	21	8	12
Vegetables	10	10	10	10
Dairy	4	0	0	0
Protein foods	7	21	11	20
Animal-source	6	10	10	10
Plant-source	1	11	1	10
Added fats and oils	0	0	0	0
12-23.9 mo non-breastfed				
Starchy Staples	37	26	36	15
Fruits	21	21	21	21
Vegetables	10	10	10	10
Dairy	15	14	16	14
Protein foods	1	19	7	24
Animal-source	1	2	2	2
Plant-source	0	17	6	23
Added fats and oils	16	10	10	16

[a] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

Table 40. Percent of energy from food groups when staple foods are increased in quantity[a]

Minimum number of staple food daily servings per week

6-8.9 mo breastfed	0 minimum	Best-case (3.5 staples)	7 minimum	14 minimum	17 minimum
Breastmilk	77	77	77	77	77
Starchy Staples	0	4	9	19	22
Fruits	0	0	0	0	0
Vegetables	7	7	5	3	1
Dairy	3	3	0	0	0
Protein foods	13	9	9	2	0
Animal-source	7	7	7	2	0
Plant-source	6	2	2	0	0
Added fats and oils	0	0	0	0	0

9-11.9 mo, breastfed	Best-case (7.4 staples)	14 minimum	21 minimum
Breastmilk	63	63	64
Starchy Staples	9	18	26
Fruits	4	0	0
Vegetables	9	6	2
Dairy	1	2	4
Protein foods	15	11	4
Animal-source	6	9	4
Plant-source	8	2	0
Added fats and oils	0	0	0

12-23.9 mo, breastfed	Best-case (14.5 staples)	21 minimum
Breastmilk	44	44
Starchy Staples	26	30
Fruits	10	8
Vegetables	10	9
Dairy	4	1
Protein foods	7	9
Animal-source	6	9
Plant-source	1	0
Added fats and oils	0	0

[a]All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age. The shaded cells show results from the feasible best-case scenario, for reference.

Breastfed infants 6-8.9 months

In the maize-only and the rice-only scenarios, the percent of energy from starchy staples was higher and the percentages of energy from dairy and protein foods were slightly lower. Increasing the minimum quantity of starchy staple foods progressively reduced the percent of energy from first dairy and vegetables, and then protein foods. As noted earlier, at 17 servings of starchy staples 99% of energy was from breast milk and staples.

Breastfed infants 9-11.9 months

In the roots/tubers/plantains-only scenario, the percent of energy from starchy staples was reduced to the minimum and the percent of energy from fruits was increased. The maize-only and rice-only scenarios caused only very small shifts.

Increasing the minimum quantity of staple foods reduced fruits, vegetables, and protein foods and slightly increased dairy. At 21 servings of starchy staples, fruits and plant-source protein foods were entirely displaced, and vegetables and animal-source protein foods were reduced but not eliminated.

Breastfed children 12-23.9 months

In the roots/tubers/plantains-only scenario, the percent of energy from starchy staples was reduced to the minimum, the percent of energy from fruits was doubled, and the percent of energy from protein foods was tripled, with increases in both animal- and plant-source protein foods. In the maize-only scenario, the percent of energy from staple foods did not change relative to the feasible best-case scenario, the percent of energy from fruit was slightly reduced, and there was an increase in animal-source protein foods. In the rice-only scenario, starchy staples were reduced (though not to the minimum) and protein foods again were nearly tripled, with increases in both animal- and plant-source protein foods.

Increasing staple foods to 21 servings per week resulted in small reductions in fruits, vegetables and dairy, and a small increase in protein foods. In this scenario, there was only limited displacement.

Non-breastfed children 12-23.9 months

In the roots/tubers/plantains-only scenario there was a reduction in the percent of energy from staple foods and from added fats and oils, and a very large increase in the percent of energy from plant-source protein foods. In the maize-only scenario, the percent of energy from staple foods did not change relative to the feasible best-case scenario, the percent of energy from added fats and oils decreased and the percent of energy from protein foods, primarily plant-source, increased. In the rice-only scenario, starchy staple foods were decreased while plant-source protein foods increased from zero to 23% of energy.

Increasing quantity of starchy staples was not modeled for this group, because the feasible best-case scenario already included the maximum of 21 daily servings per week.

3b.4. Characteristics of food patterns when sentinel unhealthy items are included

Including unhealthy items had little impact on macronutrient profiles for IYC nine months of age and older, and in all cases, macronutrients were within acceptable ranges. For infants 6-8.9 months of age, inclusion of sweetened beverages or sweet biscuits seven days a week led to lower protein and higher carbohydrate levels, as shown in **Table 41**. Less frequent inclusion of unhealthy items, and inclusion of crips/chips at any frequency, did not shift macronutrient profiles (results not shown; changes were all less than five percentage points).

Table 41. Percent of energy from macronutrients when sentinel unhealthy items are included[a, b, c, d]

	Feasible best-case	7 servings SSB	7 servings biscuits
6-8.9 mo, breastfed			
Protein	13.6	9.7	7.8
Fat	44.8	41.1	44.5
Carbohydrate	43.3	51.0	49.1

[a] SSB = sugar-sweetened beverage.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] Results are shown only for scenarios where percent of energy differed from the reference pattern by at least five percentage points. There were no differences of this size in scenarios for older infants and children.

[d] Note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%.

Table 42 shows the percent of energy from food groups when unhealthy items are included. See Annex 9 for results at the food subgroup level.

Table 42. Percent of energy from food groups when sentinel unhealthy items are included[a, b]

	Feasible best-case	1 serving SSB	3 servings SSB	7 servings SSB	1 serving biscuits	3 servings biscuits	7 servings biscuits	1 serving crisps/chips	3 servings crisps/chips	7 servings crisps/chips
6-8.9 mo, breastfed										
Breastmilk	77	77	77	77	77	77	77	77	77	77
Starchy staples	4	4	4	4	4	4	4	4	4	4
Fruits	0	0	0	0	0	0	0	0	0	0
Vegetables	7	6	6	6	6	6	2	6	6	6
Dairy	3	2	0	0	1	0	0	2	0	0
Protein foods	9	9	9	3	9	5	0	9	9	3
Animal-source[c]	7	7	7	3	7	5	0	7	7	3
Plant-source[c]	2	2	1	0	2	0	0	2	2	0
Added fats and oils	0	0	0	0	0	0	0	0	0	0
Sentinel unhealthy items	0	1	4	9	2	7	17	1	4	9
9-11.9 mo, breastfed										
Breastmilk	63	63	63	64	63	64	63	63	63	63
Starchy staples	9	7	5	4	7	4	4	8	7	4
Fruits	4	4	4	2	3	2	0	3	2	0
Vegetables	9	9	9	6	9	9	6	9	9	8
Dairy	1	1	1	2	1	1	2	1	1	1
Protein foods	15	15	15	14	15	15	9	15	15	15
Animal-source[c]	6	6	6	8	6	7	6	6	6	6
Plant-source[c]	8	8	8	6	8	8	4	8	8	8
Added fats and oils	0	0	0	0	0	0	0	0	0	0
Sentinel unhealthy items	0	1	3	8	2	6	15	1	4	8

	Feasible best-case	1 serving SSB	3 servings SSB	7 servings SSB	1 serving biscuits	3 servings biscuits	7 servings biscuits	1 serving crisps/chips	3 servings crisps/chips	7 servings crisps/chips
12-23.9 mo, breastfed										
Breastmilk	44	44	44	44	44	44	44	44	44	44
Starchy staples	26	24	22	8	24	22	6	25	25	18
Fruits	10	9	8	9	8	6	3	8	4	1
Vegetables	10	10	10	9	10	10	9	10	10	10
Dairy	4	3	2	0	3	1	0	3	2	0
Protein foods	7	8	9	17	8	9	20	7	8	11
Animal-source[c]	6	6	8	10	6	8	10	6	7	9
Plant-source[c]	1	1	1	7	1	1	9	1	1	2
Added fats and oils	0	0	0	0	0	0	0	0	0	0
Sentinel unhealthy items	0	2	5	12	3	8	19	2	7	16
12-23.9 mo, non-breastfed										
Starchy staples	37	37	33	24	36	32	23	36	35	34
Fruits	21	21	21	21	21	21	21	20	20	20
Vegetables	10	10	10	10	10	10	10	10	10	9
Dairy	15	15	14	14	15	14	14	15	14	13
Protein foods	1	1	2	6	1	2	5	1	1	1
Animal-source[c]	1	1	1	2	1	1	2	1	1	1
Plant-source[c]	0	0	1	3	0	1	3	0	0	0
Added fats and oils	16	15	15	13	14	13	8	15	12	7
Sentinel unhealthy items	0	2	5	12	3	8	18	2	7	16

[a] SSB = sugar-sweetened beverage.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

Breastfed infants 6-8.9 months of age
Since breastmilk was fixed at 77% of energy and the best-case model included the minimum required amount of starchy staple food (4% of energy), this leaves 19% of energy for other foods and beverages. As the number of servings of unhealthy items increased, the percent of energy from dairy and protein foods decreased. When sweet biscuits were included seven days a week, they displaced nearly all other complementary foods and beverages.

Breastfed infants 9-11.9 months of age
As the number of servings of unhealthy items increased, the percent of energy from starchy staples and fruits decreased. When SSB or biscuits were included seven days a week the percent of energy from vegetables and from plant-source protein foods was reduced.

Breastfed children 12-23.9 months of age
Inclusion of biscuits or crisps reduced the percent of energy from fruit. When unhealthy items were included seven days a week, starchy staples were decreased and protein foods were increased. This may reflect the fact that in the best-case models Optifood minimized protein foods after meeting all nutrient targets. Substituting unhealthy items for whole grain foods would create new gaps (particularly for minerals) and result in the selection of more nutrient-dense protein foods.

Non-breastfed children 12-23.9 months of age
Results for non-breastfed children were similar to same-aged breastfed children, with reduced starchy staples and somewhat increased protein foods when 3 or 7 servings of SSB or biscuits were included. However, instead of reducing fruits, added fats and oils were reduced when unhealthy items were included seven days a week.

3b.5. Characteristics of food patterns when fortified items are included

Including fortified items had little impact on macronutrient profiles for non-breastfed children 12-23.9 months of age and in all cases, macronutrients were within acceptable ranges. There were also no major impacts of one serving a week (any item) or of Super Cereal Plus (any frequency), for any age/feeding group.

Table 43 shows differences (from best-case) of five percentage points or larger, when MNPs and SQ-LNS were included either three or seven days a week. In general, the percent of energy from protein was reduced and fat was increased, with varying changes in percent of energy from carbohydrate. Macronutrient values (as percent of energy) fell below or exceeded recommended ranges in several instances, as shown in the table.

As with several other results for ages 12-23.9 months, the results for percent of energy from fat are an artifact of the Optifood model, where protein is minimized once all nutrient targets are met. In the case of MNPs and SQ-LNS, this resulted in selection of more added fats and oils, particularly for MNPs which meet many micronutrient needs without contributing energy.

Table 43. Percent of energy from macronutrients when fortified items are included[a, b, c, d]

	Feasible best-case	3 servings MNP	7 servings MNP	3 servings SQ-LNS	7 servings SQ-LNS
6-8.9 mo, breastfed					
Protein	13.6		8.4		7.8
Fat	44.8		47.0		52.8
Carbohydrate	43.3		46.3		40.3
9-11.9 mo, breastfed					
Protein	14.2		7.6		12.6
Fat	40.0		46.9		47.1
Carbohydrate	48.0		48.0		41.6
12-23.9 mo, breastfed					
Protein	13.7	8.7	8.0	8.4	6.0
Fat	35.0	53.5	51.4	42.6	49.5
Carbohydrate	55.1	40.8	43.6	52.8	47.6

[a] MNP = multiple micronutrient powder; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] Shaded cells indicate values that fall below or exceed Acceptable Macronutrient Distribution Ranges (AMDR) of: protein, 5-20%; fat, 30-40%; carbohydrate, 45-65% (National Academies of Sciences, Engineering, and Medicine 2019). There are no AMDR for infants. However, note that because Optifood outputs grams of protein, fat, and carbohydrate rather than kcals from these macronutrients, we used Atwater factors to convert grams to kcals and then to percent of energy. In addition, our primary food composition source database reports total carbohydrate, not available carbohydrate. Because of these two issues, our estimates of percent of energy from macronutrients are imprecise and sum to more than 100%.

[c] Results are shown only for scenarios where percent of energy differed from the reference pattern by at least five percentage points.

Table 44 shows the percent of energy from food groups when fortified items are included. See Annex 9 for results at the food subgroup level and see Annex 10 for results when assuming 5% absorption of iron. At the food group level, inclusion of fortified items resulted in numerous shifts within each age/feeding group. Patterns of change were not consistent across age/feeding groups or across types of supplements.

Table 44. Percent of energy from food groups when fortified items are included[a, b]

	Feasible best-case	1 serving MNP	3 servings MNP	7 servings MNP	1 serving SQ-LNS	3 servings SQ-LNS	7 servings SQ-LNS	1 serving SCP	3 servings SCP	7 servings SCP
6-8.9 mo, breastfed										
Breastmilk	77	77	77	77	77	77	77	77	77	77
Starchy staples	4	4	4	5	4	4	4	3	1	0
Fruits	0	0	0	1	0	0	0	0	0	0
Vegetables	7	7	7	6	4	5	0	7	7	1
Dairy	3	2	2	6	0	0	0	1	0	0
Protein foods	9	9	9	1	12	6	0	9	6	0
Animal-source[c]	7	4	3	1	3	3	0	7	6	0
Plant-source[c]	2	5	6	0	8	2	0	2	0	0
Added fats and oils	0	0	0	4	0	0	0	0	0	0
Fortified items	0	0	0	0	3	8	18	3	10	22
9-11.9 mo, breastfed										
Breastmilk	63	63	63	63	63	63	64	63	63	63
Starchy staples	9	9	9	7	10	7	4	7	4	4
Fruits	4	4	4	8	2	0	0	4	3	1
Vegetables	9	9	9	5	7	7	4	8	6	5
Dairy	1	1	1	5	0	0	0	0	0	0
Protein foods	15	15	15	1	15	15	13	15	15	6
Animal-source[c]	6	6	6	1	6	6	5	6	6	5
Plant-source[c]	8	8	8	0	8	8	8	8	8	1
Added fats and oils	0	0	0	11	0	0	0	0	0	0
Fortified items	0	0	0	0	2	7	16	3	9	20

	Feasible best-case	1 serving MNP	3 servings MNP	7 servings MNP	1 serving SQ-LNS	3 servings SQ-LNS	7 servings SQ-LNS	1 serving SCP	3 servings SCP	7 servings SCP
12-23.9 mo, breastfed										
Breastmilk	44	44	44	44	44	44	44	44	44	44
Starchy staples	26	21	6	4	18	9	4	18	13	7
Fruits	10	14	14	17	18	17	18	16	15	7
Vegetables	10	9	7	6	10	9	3	10	10	9
Dairy	4	10	12	13	4	3	0	1	0	0
Protein foods	7	1	0	0	4	1	1	7	5	3
Animal-source[c]	6	1	0	0	2	1	1	6	4	1
Plant-source[c]	1	0	0	0	1	0	0	1	1	2
Added fats and oils	0	0	16	16	0	10	16	0	0	0
Fortified items	0	0	0	0	2	6	14	3	10	22
12-23.9 mo, non-breastfed										
Starchy staples	37	33	28	28	31	31	31	35	26	14
Fruits	21	25	26	26	26	26	26	20	24	25
Vegetables	10	9	5	5	9	9	5	10	9	9
Dairy	15	16	22	22	14	10	4	13	11	2
Protein foods	1	1	2	2	1	3	4	1	1	4
Animal-source[c]	1	1	2	2	1	3	4	1	1	2
Plant-source[c]	0	0	0	0	0	0	0	0	0	2
Added fats and oils	16	16	16	16	16	16	16	16	16	16
Fortified items	0	0	0	0	2	6	14	4	13	31

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] All models are for middle energy levels, i.e., the estimated energy requirement averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

Breastfed infants 6-8.9 months of age

When SQ-LNS or Super Cereal Plus were included seven days a week, they displaced most or all vegetables, dairy, and protein foods. When MNPs were included seven days a week nearly all protein foods were eliminated, but dairy was increased, perhaps because there is no calcium in the MNPs. At lower frequencies (one or three days per week) animal-source protein foods were decreased when MNPs or SQ-LNS were included, but not when Super Cereal Plus was included.

The large reduction in protein foods when MNPs were included seven days a weeks reflects the fact that the iron target was met, and Optifood proceeded to minimize protein.

Breastfed infants 9-11.9 months of age

MNPs impacted patterns only when included seven days a week. In this scenario, all target nutrient needs were met. Vegetables were decreased and protein foods were nearly eliminated, while fruits, dairy and added fats and oils were increased. Inclusion of SQ-LNS seven days a week decreased vegetables, eliminated fruits, and reduced starchy staples to the minimum allowed, but did not substantially reduce protein foods for this age group, likely because iron needs were not met. Super Cereal Plus had little impact when included one or three days, but when included seven days a week decreased intake of all other food groups.

Breastfed infants 12-23.9 months of age

Generally, inclusion of these items had the largest impact on patterns for this age/feeding group. Inclusion of fortified items decreased starchy staple foods, and increased fruits in most scenarios. MNPs and SQ-LNS decreased animal-source protein foods and substantially increased added fats and oils; they also decreased vegetables when included seven days a week. When included seven days a week, Super Cereal Plus eliminated dairy and reduced all other food groups except plant-source protein foods. MNPs increased dairy, while the other fortified items decreased dairy.

Non-breastfed infants 12-23.9 months of age

For this group, inclusion of fortified items increased the percent of energy from fruits. MNPs and SQ-LNS reduced vegetables, but Super Cereal Plus did not. There were also mixed impacts on dairy, with MNPs once again increasing it and both SQ-LNS and Super Cereal Plus decreasing dairy, particularly when they were included seven days a week. There were small increases in protein foods in several scenarios, but the percent of energy from protein foods remained low, reflecting the lack of gaps in target nutrients in this age/feeding group.

3c. Examples of four food patterns

Each of the food pattern patterns described above could be met with a wide variety of foods from within the food subgroups, and exact quantities would vary depending on items selected. Further, the total weekly quantities for each food subgroup could be divided differently, depending on the number of days the IYC is assumed to eat each item. In **Tables 45-48**, we provide a single example weekly food pattern for each of four food patterns, to illustrate approximate quantities and frequencies under these scenarios:

- Breastfed infants 6-8.9 months: Feasible best-case pattern, all food subgroups allowed
- Breastfed infants 9-11.9 months: No whole grain foods
- Breastfed children 12-23.9 months: No liver or small fish eaten with bones
- Non-breastfed children 12-23.9 months: No meat, liver, poultry or fish

These example weekly food patterns are not recommendations, but rather illustrations so readers can assess the feasibility and face validity of the model solutions.

Table 45. Example weekly food pattern based on the feasible best-case pattern for a breastfed infant 6-8.9 months of age[a]

Example food item	Total grams per week	Number of days per week	Amount per day
Breast milk	5306	7	~0.73 liter = ~ 3.1 cups
Dry wholegrain oat breakfast cereal	52.5	7	1/4 cup
Summary: Very limited amount of whole grain starchy staple foods, daily			
Spinach, strained	160	4	2.5 tablespoons
Broccoli, boiled, drained, chopped	150	6	2.5 tablespoons
Tomatoes, stewed	97.5	4	4 tablespoons
Peas, strained	160	4	2.5 tablespoons
Corn, creamed, strained	264	6	3 tablespoons
Summary: A total of about one cup per day of diverse vegetables, with five different subgroups throughout the week			
Milk	78	1	1/3 cup
Cottage cheese	25	1	2 tablespoons
Tofu, mashed	50	2	1.5 tablespoons
Beef, strained	90	3	2 tablespoons
Chicken liver, simmered	40	2	1/2 liver
Sardines, canned, drained, pureed	45	3	1.5 tablespoons
Summary: Either beef or sardines (almost) daily, a small amount of liver and tofu each twice a week, and milk and cheese each one day a week			

[a] Quantities are approximate and are based on total weekly grams divided by grams per cup, tablespoon, etc. from appropriate example items at the US Food Data Central website (https://fdc.nal.usda.gov/index.html). Nutrient content of the example food pattern is not the same as the nutrient content in the model solution, where food subgroup nutrient profiles were used.

Table 46. Example weekly food pattern based on the feasible best-case pattern for a breastfed infant 9-11.9 months of age, modified by eliminating all whole grain foods[a]

Example food item	Total grams per week	Number of days per week	Amount per day
Breast milk	4914	7	~0.68 liter = ~2.8 cups
Potatoes, boiled	210	3	1/2 medium
Summary: Very limited starchy staple foods			
Papaya, mashed	180	3	4 tablespoons
Strawberries, sliced	50	2	2.5 tablespoons
Guava, peeled	30	1	1/2 fruit
Avocado, pureed	102	2	3.5 tablespoons
Applesauce, unsweetened	63	1	4 tablespoons
Summary: One or occasionally two types of fruit per day for a total of about one cup, with five different subgroups throughout the week			
Spinach, strained	160	4	2.5 tablespoons
Broccoli, boiled, drained, chopped	62.5	3	2 tablespoons
Carrots, strained	420	7	4 tablespoons
Peas, strained	160	4	2.5 tablespoons
Corn, creamed, strained	280	6	3 tablespoons
Summary: A total of about one cup per day of diverse vegetables, with five different subgroups throughout the week			
Milk	72	1	1/3 cup
Summary: A small amount of fluid milk, once a week			
Lentils, boiled	238	5	4 tablespoons
Tofu	50	2	1.5 tablespoons
Beef, strained	90	3	2 tablespoons
Chicken liver, simmered	40	2	1/2 liver
Sardines, canned, drained, pureed	45	3	1.5 tablespoons
Summary: Either beef or sardines (almost) daily, lentils or other pulses five days a week, and small amounts of liver and tofu each twice a week			

[a] Quantities are approximate and are based on total weekly grams divided by grams per cup, tablespoon, etc. from appropriate example items at the US Food Data Central website (https://fdc.nal.usda.gov/index.html). USDA yield factors were used as needed to translate grams of legumes in the model solutions into boiled forms. This table shows approximate amounts of all foods in forms as eaten. Nutrient content of the example food pattern is not the same as the nutrient content in the model solution, where food subgroup nutrient profiles were used.

Table 47. Example weekly food pattern based on the feasible best-case pattern for a breastfed child 12-23.9 months of age, modified by eliminating liver and small fish eaten with bones[a]

Example food item	Total grams per week	Number of days per week	Amount per day
Breast milk	4088	7	~0.56 liter = ~2.4 cups
Bread, whole wheat	260	7	1 slice
Summary: One slice of whole grain bread daily			
Strawberries, sliced	195	3	6 tablespoons
Summary: Berries about three days a week			
Spinach, boiled	420	7	5 tablespoons
Broccoli, boiled, chopped	360	6	6 tablespoons
Sweet potato, mashed	560	7	4 tablespoons
Peas, boiled	160	4	4 tablespoons
Corn, boiled	160	4	4 tablespoons
Summary: A total of one cup or a little more per day of diverse vegetables, with five different subgroups throughout the week			
Milk	720	6	1/2 cup
Summary: About one-half cup of full-fat milk almost daily			
Egg, scrambled	350	7	1 egg
Lentils, boiled	430	6	6 tablespoons
Tofu	60	2	2 tablespoons
Beef, prepared for toddler	200	5	2.5 tablespoons
Summary: One egg daily, lentils or other pulses almost daily, beef five days a week, and tofu twice a week			

[a] Quantities are approximate and are based on total weekly grams divided by grams per cup, tablespoon, etc. from appropriate example items at the US Food Data Central website (https://fdc.nal.usda.gov/index.html). USDA yield factors were used as needed to translate grams of legumes in the model solutions into boiled forms. This table shows approximate amounts of all foods in forms as eaten. Nutrient content of the example food pattern is not the same as the nutrient content in the model solution, where food subgroup nutrient profiles were used.

Table 48. Example weekly food pattern based on the feasible best-case pattern for a non-breastfed child 12-23.9 months of age, modified by eliminating all meat, liver, poultry and fish[a]

Example food item	Total grams per week	Number of days per week	Approximate amounts per day
Brown rice, boiled	850	7	2/3 cup
Dry wholegrain oat breakfast cereal	120	7	2/3 cup
Bread, whole wheat	350	7	1.5 slices
Potatoes, boiled	182	3	1/2 medium
Summary: whole grain breakfast cereal, brown rice, and whole grain bread daily, and potatoes 3 times a week			
Papaya, mashed	580	5	8 tablespoons
Strawberries, sliced	195	3	6 tablespoons
Avocado, pureed	240	4	4 tablespoons
Applesauce, unsweetened	650	7	6 tablespoons
Summary: A total of about one and one-half cups per day of diverse fruits, with four different subgroups throughout the week		19	
Spinach, boiled	420	7	5 tablespoons
Broccoli, boiled, chopped	276	5	6 tablespoons
Sweet potato, mashed	560	7	4 tablespoons
Peas, boiled	160	4	4 tablespoons
Corn, boiled	216	5	4 tablespoons
Summary: A total of about one and one-half cups per day of diverse vegetables, with five different subgroups throughout the week			
Milk	1330	7	3/4 cup
Summary: About 3/4 cup of full-fat milk daily			
Egg, scrambled	55	1	1 egg
Tofu	90	3	2 tablespoons
Summary: Eggs once a week and tofu three days a week			
Butter	23.4	5	1 teaspoons
Oil, canola	70	7	2 teaspoons
Summary: One teaspoon of butter most days and two teaspoons of oil daily			

[a] Quantities are approximate and are based on total weekly grams divided by grams per cup, tablespoon, etc. from appropriate example items at the US Food Data Central website (https://fdc.nal.usda.gov/index.html). USDA yield factors were used as needed to translate grams of dry grains in the model solutions into boiled forms. This table shows approximate amounts of all foods in forms as eaten. Nutrient content of the example food pattern is not the same as the nutrient content in the model solution, where food subgroup nutrient profiles were used.

3d. Results for scenarios approximating real-world food patterns

We used data from three settings to develop scenarios approximating real-world food patterns: rural Bangladesh, rural southern Malawi, and Mexico. We based the scenarios on the percent of energy in the observed diets from the various food groups and subgroups. Results for nutrient gaps are summarized here, and more extensive tables are provided in **Annex 11**.

In Bangladesh and Malawi, the diets were dominated by starchy staple foods (57%-68% of the energy from complementary foods), while diets in Mexico had more moderate amounts of starchy staple foods and more dairy and other animal-source foods. **Table 49** compares the percent of total energy from food groups to best-case patterns at the low and middle energy levels.

For Bangladesh and Malawi, the percent of energy from starchy staples, added fats and oils, and unhealthy items were all higher than in the best-case scenarios (noting that the last was not allowed in best-case scenarios). The percent of energy from vegetables and from animal-source protein foods were much lower than in the best-case scenarios.

For Mexico, the percent of energy from starchy staple foods was similar to the best-case level in infancy, but lower for non-breastfed children. In the best-case scenarios for non-breastfed children, the percent of starchy staples is very high. The percent of energy from vegetables was lower for all age groups, while the percent of energy from dairy was higher. The percent of energy from protein foods was lower in infancy, but higher for the non-breastfed children, as protein was being minimized in the best-case scenario. The percent of energy from unhealthy items was particularly high for non-breastfed children in Mexico, at 21% of total energy intake.

As shown in **Table 50**, diets were deficient in numerous vitamins and minerals, and were worse in Bangladesh and Malawi than in Mexico. The NRVs were met for all age groups in all settings only for the following: Protein; α-linolenic acid; linoleic acid; vitamin A; vitamin C; and niacin equivalents.

Iron and vitamin D were very low in all diets, as in the modeled scenarios, but B vitamins and all minerals were also well below NRVs for some or all age groups in Bangladesh and Malawi. Several vitamins and minerals were also low in the Mexican scenarios. Compared to the best-case scenarios the gaps between the nutrient content of the diet and the NRVs were larger, with numerous nutrients below 50% of the NRV in Bangladesh and Malawi.[21]

[21] We assessed whether this was due to use of the low energy level by comparing gaps in real-world vs. best-case scenarios using both the low energy level and the middle energy level for Bangladesh and Malawi. Patterns of gaps were similar, and gaps remained both more numerous and larger in the real-world scenarios when using the middle energy level (results not shown).

Table 49. Percent of energy from food groups for real-world and best-case food patterns[a]

	Bangladesh	Malawi	Mexico	Best-case low energy level	Best-case middle energy level
6-8.9 mo breastfed					
Breastmilk	77	77	77	77	77
Starchy staples	14	15	5	5	4
Fruits	0	0	2	0	0
Vegetables	0	0	1	8	7
Dairy	4	0	8	0	3
Protein foods	1	3	3	9	9
Animal-source[b]	1	0	2	9	7
Plant-source[b]	0	3	1	0	2
Added fats and oils	1	3	1	0	0
Unhealthy foods	3	2	4	0	0
9-11.9 mo breastfed					
Breastmilk	64	64	63	64	63
Starchy staples	22	24	7	5	9
Fruits	0	0	3	0	4
Vegetables	0	0	1	9	9
Dairy	6	0	13	4	1
Protein foods	2	4	4	18	15
Animal-source[b]	2	0	3	8	6
Plant-source[b]	0	4	1	10	8
Added fats and oils	2	5	2	0	0
Unhealthy foods	5	3	6	0	0
12-23.9 mo breastfed					
Breastmilk	44	44		44	44
Starchy Staples	38	32		10	26
Fruits	0	0		3	10
Vegetables	1	1		13	10
Dairy	3	1		0	4
Protein foods	3	7		30	7
Animal-source[b]	2	2		14	6
Plant-source[b]	1	5		16	1
Added fats and oils	4	9		0	0
Unhealthy foods	6	6		0	0

	Bangladesh	Malawi	Mexico	Best-case low energy level	Best-case middle energy level
12-23.9 mo non-breastfed					
Starchy staples			24		37
Fruits			7		21
Vegetables			2		10
Dairy			28		15
Protein foods			12		1
Animal-source[b]			10		1
Plant-source[b]			2		0
Added fats and oils			5		16
Unhealthy foods			21		0

[a] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[b] Animal-source protein foods include meat, liver, poultry, small and large fish, and eggs. Plant-source protein foods include legumes, soy foods, nuts, and seeds.

Table 50. Percent of nutrient reference values for scenarios approximating real-world food patterns[a, b]

	Bangladesh – low energy level			Malawi - low energy level			Mexico – middle energy level		
Age group	**6-8.9 mo**	**9-11.9 mo**	**12-23.9 mo**	**6-8.9 mo**	**9-11.9 mo**	**12-15.9 mo**	**6-8.9 mo**	**9-11.9 mo**	**12-23.9 mo**
Breastfeeding status	**BF**	**BF**	**BF**	**BF**	**BF**	**BF**	**BF**	**BF**	**Non-BF**
Target nutrients									
Fat			92.5						92.1
Thiamin	52.5	61.7	41.6	60.6	76.5	51.4	75.9	94.0	88.5
Riboflavin	78.7	92.4	52.9	68.4	73.5	49.5			
Vitamin B6	36.8	50.2	36.2	47.1	69.0	45.8	68.2		
Folate	73.2	79.1	54.9	76.0	84.2	57.4			92.3
Choline	69.2	75.0	72.4	63.5	64.5	68.5	92.9		
Vitamin B12	82.6		68.7	54.3	58.1	94.2			
Calcium	57.2	67.8	35.5	47.5	50.0	35.2	91.6		
Iron 10% absorption	2.9	5.3	17.9	6.7	12.2	29.8	5.4	9.8	49.8
Iron 5% absorption	1.4	2.6	8.9	3.3	6.1	14.9	2.7	4.9	24.9
Potassium	45.9	54.0	54.8	47.2	56.5	61.1	77.3		
Zinc	29.3	39.4	34.0	34.0	48.0	42.4	46.4	65.8	97.6
Non-target nutrients									
Carbohydrate	66.3	81.2	72.9	66.2	80.9	66.3	77.2	89.3	89.3
Fiber[c]	*n/a*	*n/a*	28.4	*n/a*	*n/a*	49.1	*n/a*	*n/a*	93.9
Vitamin D	1.3	2.4	3.9	0.3	0.5	5.0	1.5	2.7	8.5
Copper	42.5	52.0	82.6	56.5	77.6		59.2	74.5	
Magnesium	39.4	50.2	65.9	58.8	85.7		62.0	84.5	
Phosphorus	83.8		45.9	87.8		57.8			

[a] BF = breastfed. Nutrients are included if the content of the diet was less than 98% of an NRV for any of the scenarios. Values at or above 98% are not shown. Values less than 50% of the NRV are highlighted in orange, and values from 50% to 74.9% of the NRV are highlighted in gold.

[b] Low energy levels are the estimated energy requirement (EER) of girls at the low end of each age range and the 25th percentile for weight-for-age. Middle energy levels are the EER averaged for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] There are no reference values for fiber in infancy.

Tables 51-53 show the impact on nutrient gaps when either MNPs, SQ-LNS or Super Cereal Plus were included seven days a week. While some nutrient gaps were eliminated, some remained.

All three fortified items eliminated gaps for some or all B vitamins. MNPs and SQ-LNS eliminated gaps for zinc and copper, and SQ-LNS eliminated gaps for calcium for infants and substantially reduced gaps for children 12-23.9 months of age. In Bangladesh and Malawi gaps for choline and potassium remained, as did gaps for magnesium and phosphorus for some age groups.

As in the modeling, iron gaps were eliminated or reduced to the greatest extent by MNPs, followed by SQ-LNS, with Super Cereal Plus having a much smaller impact. However, particularly when assuming lower absorption, iron gaps remained and were very large in some scenarios (see tables).

Also as in the modeling, ULs for zinc and copper were sometimes exceeded. The UL for zinc was exceeded in all scenarios with SQ-LNS and in more than half of the scenarios with MNPs. The UL for copper was exceeded in one scenario with MNPs. See Annex 11 for details.

Table 51. Percent of selected nutrient reference values in the Bangladesh scenario when fortified items are included daily[a, b, c]

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
6-8.9 mo, breastfed				
Target nutrients				
Thiamin	52.5			58.7
Riboflavin	78.7			
Vitamin B6	36.8			
Folate	73.2			
Choline	69.2	69.2	65.3	68.3
Vitamin B12	82.6			
Calcium	57.2	57.2		80.9
Iron (10%)	2.9	93.8	54.6	10.2
Iron (5%)	1.4	46.9	27.3	5.1
Potassium	45.9	45.9	60.8	40.5
Zinc	29.3			65.3
Non-target nutrients				
Carbohydrate	66.3	66.3	51.6	64.9
Vitamin D	1.3	51.3	50.0	30.9
Copper	42.5			54.2
Magnesium	39.4	39.4	75.1	65.1
Phosphorus	83.8	83.8		
9-11.9 mo, breastfed				
Target nutrients				
Thiamin	61.7			72.4
Riboflavin	92.4			
Vitamin B6	50.2			
Folate	79.1			
Choline	75.0	75.0	63.5	82.9
Calcium	67.8	67.8		
Iron (10%)	5.3	96.2	57.0	12.9
Iron (5%)	2.6	48.1	28.5	6.5
Potassium	54.0	54.0	62.5	55.4
Zinc	39.4			77.9
Non-target nutrients				
Carbohydrate	81.2	81.2	71.7	73.8
Vitamin D	2.4	52.4	50.0	34.3
Copper	52.0			61.9
Magnesium	50.2	50.2	83.4	79.3

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
12-23.9 mo, breastfed				
Target nutrients				
Fat	92.5	92.5		
Thiamin	41.6		89.7	51.6
Riboflavin	52.9			
Vitamin B6	36.2		72.4	
Folate	54.9			93.7
Choline	72.4	72.4	60.2	87.4
Vitamin B12	68.7		74.4	
Calcium	35.5	35.5	83.8	72.9
Iron (10%)	17.9		95.9	37.6
Iron (5%)	8.9	80.4	47.9	18.8
Potassium	54.8	54.8	59.7	56.4
Zinc	34.0			77.4
Non-target nutrients				
Carbohydrate	72.9	72.9	68.5	63.9
Fiber	28.4	28.4	21.0	28.8
Vitamin D	3.9	53.9	50.0	57.8
Copper	82.6			
Magnesium	65.9	65.9	95.4	
Phosphorus	45.9	45.9	71.1	61.7

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] The 'original' scenario approximates the real-world setting, and was developed based on the percent of energy from food subgroups in survey data, except for breast milk. The percent of energy from breast milk was fixed for each age group, as in the modeled scenarios. The total energy in the diet was the estimated energy requirement (EER) for a small infant/child in each age group; specifically, we calculated the EER for a girl at the low end of each age range and the 25th percentile for weight-for-age.

[c] Nutrients are included if the content of the diet was less than 98% of an NRV for any of the scenarios. Values at or above 98% are not shown. Values less than 50% of the NRV are highlighted in orange, and values from 50% to 74.9% of the NRV are highlighted in gold.

Table 52. Percent of selected nutrient reference values in the Malawi scenario when fortified items are included daily[a, b, c]

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
6-8.9 mo, breastfed				
Target nutrients				
Thiamin	60.6			59.5
Riboflavin	68.4			
Vitamin B6	47.1			
Folate	76.0			
Choline	63.5	63.5	65.3	68.5
Vitamin B12	54.3			
Calcium	47.5	47.5		79.2
Iron (10%)	6.7	97.6	54.5	10.8
Iron (5%)	3.3	87.7	27.3	5.4
Potassium	47.2	47.2	60.7	40.6
Zinc	34.0			65.8
Non-target nutrients				
Carbohydrate	66.2	66.2	51.3	65.2
Vitamin D	0.3	50.3	50.0	31.1
Copper	56.5			56.2
Magnesium	58.8	58.8	75.0	65.7
Phosphorus	87.8	87.8		
9-11.9 mo, breastfed				
Target nutrients				
Thiamin	76.5			74.4
Riboflavin	73.5			
Vitamin B6	69.0			
Folate	84.2			
Choline	64.5	64.5	66.5	70.3
Vitamin B12	58.1			
Calcium	50.0	50.0		84.9
Iron (10%)	12.2		61.4	16.7
Iron (5%)	6.1	51.6	30.7	8.4
Potassium	56.5	56.5	69.9	52.6
Zinc	48.0			79.7
Non-target nutrients				
Carbohydrate	80.9	80.9	71.1	73.9
Vitamin D	0.5	50.5	50.0	32.4
Copper	77.6			78.8
Magnesium	85.7	85.7		93.5

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
12-23.9 mo, breastfed				
Target nutrients				
Thiamin	51.4			49.2
Riboflavin	49.5			
Vitamin B6	45.8		86.0	
Folate	57.4			93.7
Choline	68.5	68.5	72.5	79.6
Vitamin B12	94.2			
Calcium	35.2	35.2	93.8	72.0
Iron (10%)	29.8			41.7
Iron (5%)	14.9	86.3	55.0	20.8
Potassium	61.1	61.1	73.1	54.8
Zinc	42.4			78.5
Non-target nutrients				
Carbohydrate	66.3	66.3	63.7	57.7
Fiber	49.1	49.1	43.9	30.5
Vitamin D	5.0	55.0	55.0	58.9
Phosphorus	57.8	57.8	94.3	63.2

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] The 'original' scenario approximates the real-world setting, and was developed based on the percent of energy from food subgroups in survey data, except for breast milk. The percent of energy from breast milk was fixed for each age group, as in the modeled scenarios. The total energy in the diet was the estimated energy requirement (EER) for a small infant/child in each age group; specifically, we calculated the EER for a girl at the low end of each age range and the 25th percentile for weight-for-age.

[c] Nutrients are included if the content of the diet was less than 98% of an NRV for any of the scenarios. Values at or above 98% are not shown. Values less than 50% of the NRV are highlighted in orange, and values from 50% to 74.9% of the NRV are highlighted in gold.

Table 53. Percent of selected nutrient reference values in the Mexico scenario when fortified items are included daily[a, b, c]

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
6-8.9 mo, breastfed				
Target nutrients				
Thiamin	75.9			72.6
Vitamin B6	68.2			
Choline	92.9	92.9	80.6	84.5
Calcium	91.6	91.6		
Iron (10%)	5.4	96.3	56.2	12.8
Iron (5%)	2.7	48.2	28.1	6.4
Potassium	77.3	77.3	73.0	49.8
Zinc	46.4			81.1
Non-target nutrients				
Carbohydrate	77.2	77.2	68.9	80.5
Vitamin D	1.5	51.5	50.0	38.6
Copper	59.2			67.3
Magnesium	62.0	62.0	88.1	80.7
9-11.9 mo, breastfed				
Target nutrients				
Thiamin	94.0			95.0
Choline			97.4	
Iron (10%)	9.8		60.1	18.1
Iron (5%)	4.9	50.3	30.0	9.0
Potassium			97.9	83.0
Zinc	65.8			
Non-target nutrients				
Carbohydrate	89.3	89.3	75.5	85.3
Vitamin D	2.7	52.7	52.1	41.0
Copper	74.5			82.3
Magnesium	84.5	84.5		

	Original	7 servings MNP	7 servings SQ-LNS	7 servings SCP
12-23.9 mo, non-breastfed				
Target nutrients				
Fat	92.1	92.1		
Thiamin	88.5			85.4
Folate	92.3			
Iron (10%)	49.8			67.3
Iron (5%)	24.9	96.3	66.7	33.6
Zinc	97.6			
Non-target nutrients				
Carbohydrate	89.3	89.3	78.9	79.8
Fiber	93.9	93.9	91.6	67.6
Vitamin D	8.5	58.5	58.5	80.0

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement.

[b] The 'original' scenario approximates the real-world setting, and was developed based on the percent of energy from food subgroups in survey data, except for breast milk. The percent of energy from breast milk was fixed for each age group, as in the modeled scenarios. The total energy in the diet was the estimated energy requirement (EER) for an average size child in each age group; specifically, we averaged the EER for boys and girls at the mid-point of the age range and at the 50th percentile for weight-for-age.

[c] Nutrients are included if the content of the diet was less than 98% of an NRV for any of the scenarios. Values at or above 98% are not shown. Values less than 50% of the NRV are highlighted in orange, and values from 50% to 74.9% of the NRV are highlighted in gold.

4. Summary and discussion

In this section, we first summarize results for feasible and liberalized best-case food patterns, including the sensitivity analyses assuming a lower level of absorption for iron. These analyses aimed to answer the question 'Can target nutrient needs be met with unfortified best-case food patterns?'. We then summarize the impacts of the various modifications to the food patterns, organizing the discussion by age/feeding group. We pay particular note to the impact of inclusion of fortified items designed for IYC, as this was a key question identified by the GDG. Next, we summarize results for the scenarios approximating real-world food patterns. This is followed by discussion of the strengths and limitations of our work, and a final summary of key results.

4.1. Can target nutrient needs be met with unfortified best-case food patterns?

We first modeled weekly feasible best-case food patterns to establish whether target nutrient needs could be met with unfortified foods and beverages, given a fixed percent of energy from breast milk at each age. Where feasible best-case patterns could not meet all target nutrient needs, we modeled liberalized best-case food patterns to see if these could fill gaps.

Except for iron in infancy, feasible best-case food patterns could meet all target nutrient needs at the middle and high energy levels. For the low energy level for the youngest infants only (6-8.9 months of age) there were additional gaps for calcium, potassium, and zinc. Across all energy levels and the two age groups in infancy, the iron content of the modeled food patterns ranged from 24 to 45% of the NRV, increasing as the energy level increased.

The liberalized best-case food patterns were modelled only for infants (all energy levels) because for children the feasible best-case food patterns met all nutrient targets. The liberalized patterns allowed up to seven daily servings per week for all food subgroups. They reduced but did not eliminate the iron gaps in infancy. The iron content of the liberalized food patterns ranged from 41% to 71% of the NRV.

All feasible best-case food patterns met AMDR for children 12-23.9 months of age. There are no AMDRs in infancy, but macronutrient profiles were reasonable, with protein providing 13-16% of energy, fat providing 40-45% of energy, and carbohydrate providing 43-49% of energy.

All food patterns were low in the non-target nutrient vitamin D. The NRV assumes minimal exposure to sunlight. Also, since vitamin D was not a target nutrient, our analyses did not optimize the vitamin D content of the model solutions. Still, these very low values merit consideration; model solutions were at 3-24% percent of NRV in the feasible food patterns and 7-11% of NRV in the liberalized food patterns. Note that our modeling was of unfortified foods only, and fortification (and/or supplementation for breastfed infants) is in place in some countries.

Except for the high energy level patterns in the oldest age group, all food patterns were also below the NRVs for carbohydrate. Not meeting these NRVs may not be a concern, given that the macronutrient distributions are reasonable, and given the basis for the NRVs.[22]

We also examined nutrient quantities against ULs. The UL for copper (1 mg) was slightly exceeded (≤ 1.1 mg) in most food patterns for children 12-23.9 months of age (there is no UL defined for infancy). The

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[22] The NRV in infancy was based on the sum of carbohydrate in 0.6 liter of breast milk plus the median carbohydrate intake in the third round of US NHANES (round III, 1988-1994) (Institute of Medicine 2005). The authors also note that *'it is likely that infants also may grow and develop normally on a very low or nearly carbohydrate-free diet'* (p. 281). The NRV for the second year of life is the same as for adults and based on supplying glucose to the brain. However, the same document notes that the requirement is related to the weight of the brain and also notes that brain growth is not complete until five years of age (p. 284).

UL for copper is set based on the endpoint of liver damage in individuals with defects in copper homeostasis. The level was extrapolated downwards from adulthood, based on body weight (Institute of Medicine 2001). The ULs for zinc were also exceeded in a number of scenarios, with the largest excesses in scenarios with daily SQ-LNS (approximately double the UL in infancy, and 2-3 mg above the UL for children). It is unclear to the authors whether the values we report here are of concern.

All feasible best-case food patterns were diverse, and diversity increased with age and with energy level, ranging from 10 to 20 food subgroups per week. Liberalized food patterns – where larger weekly amounts of each subgroup were allowed – included fewer food subgroups but remained diverse. Food patterns included from five to seven of the eight food groups in the WHO/UNICEF IYCF indicator for diversity.

Feasible best-case food patterns for the four lowest energy levels (all three energy levels for 6-8.9 months and the low energy level for 9-11.9 months) included the minimum allowable amount of staple foods, providing 4-5% of energy, and only whole grain breakfast cereals were selected. This is an extremely small amount, namely 7.5 grams of whole grain breakfast cereal per day.

Food patterns for the next three energy levels (middle and high energy levels for 9-11.9 months and the low level for breastfed children 12-23.9 months of age) included 9-13% of energy from starchy staples. For the next three (middle and high energy levels for breastfed children 12-23.9 months of age and the low level for non-breastfed children), amounts remained moderate at 24-26% of energy.

For non-breastfed children at the middle and high energy levels the percent of energy from staple foods was high at 37-38% of energy, reflecting the fact that in this scenario, Optifood was minimizing protein. For all age groups, the selected staple food subgroups were primarily whole grains/whole grain products, whereas refined grain products are more typical in many settings.

All feasible best-case food patterns included animal-source protein foods and diverse vegetable subgroups. Most (10 of 12) also included plant-source protein foods. Except for the youngest infants, all food patterns included fruit. Small amounts of dairy were included in five of nine food patterns for breastfed IYC, and larger amounts were included in all three food patterns for non-breastfed infants.

The maximum allowed weekly quantity of vegetables was selected in all twelve of the feasible best-case food patterns, and this was also true for the subgroup of dark green leafy vegetables. Immature peas/beans and liver were each selected at the maximum allowed amount in eleven of twelve scenarios.

Besides the small amount of staple foods for younger/smaller infants, perhaps the biggest differences between the best-case food patterns and typical IYC food patterns are in the quantity and subgroup diversity for vegetables and the subgroup diversity for protein foods.

Our parameters allowing this were based on the high end of observed distributions within the data sets. We based quantities on medians observed in countries with high consumption, and we based the allowed number of daily servings per week for each food group on the 90th percentile of diversity in countries with relatively high diversity.

Note however that intakes with the subgroup diversity reflected in our parameters were observed in at least one-third of the data sets. Except for vegetables for infants, where the highest values were all from Europe, high levels of diversity for vegetables and/or protein foods were found from settings in various global regions and at all country income levels. We interpret this to mean that for those with economic and physical access to diverse foods, high subgroup diversity was feasible and culturally appropriate in a wide variety of country settings.

4.2. What happens if iron absorption is lower?

Because feasible best-case food patterns for children 12-23.9 months of age were low in flesh foods yet had no gap for iron, we modeled additional scenarios (sensitivity analyses) with a lower assumption of 5% for absorption of iron, and with no flesh foods allowed. In these scenarios, the feasible best-case food patterns had significant gaps for iron for both breastfed (47% of NRV) and non-breastfed children (65% of NRV). There were no other gaps for target nutrients (gaps for carbohydrate and vitamin D remained).

Food patterns differed between the higher and lower absorption scenarios, with a higher percent of energy from protein and a lower percent of energy from carbohydrates in the lower absorption scenarios. Among food groups, the largest differences were in fruits (lower amounts with lower absorption) and protein foods (markedly higher amounts of eggs and plant-source protein foods with lower absorption and no flesh foods allowed).

4.3. What happens when food patterns are modified?

We modeled a series of modifications to food patterns, in most cases using the same quantity and frequency parameters as for the feasible best-case patterns. To make the total number of models manageable, we restricted these modifications to the middle energy level in each age/feeding group.

In summary, most of the modifications had major impacts on nutrient gaps for the youngest age group, where there were only ~150 kilocalories available for complementary foods and beverages. There were fewer impacts for older IYC, and only from certain modifications.

Certain of the modified food patterns exceeded AMDRs and/or ULs for copper and/or zinc. We note here that if we aimed to develop concrete and specific food-based recommendations or guidelines, it may have been possible to iterate the modeling to reach broadly similar food patterns, but which would not exceed the AMDRs or ULs. However, our objective was not to develop food-based recommendations but rather to answer the identified research questions, which are slightly different. Also, given the very large number of models we ran, it was not feasible to iterate further to address excesses.

4.3.1. Modifying food patterns for breastfed infants 6-8.9 months of age

For this age group, many of the modifications resulted in additional nutrient gaps. The most common additional nutrient gaps (that is, in addition to iron, carbohydrate and vitamin D) were for numerous other minerals, but occasionally there were gaps for B vitamins.

Gaps for iron increased and/or new gaps were introduced when we modelled food patterns where we:

1. Eliminated food groups, subgroups, or combinations;
2. Restricted staple foods to one type;
3. Increased the quantity of staple foods; or
4. Introduced unhealthy items.

Elimination of food groups or subgroups increased the gap for iron and introduced new gaps (in parentheses) for the following: no whole grains (zinc, thiamin, magnesium); no vegetables (calcium, potassium, zinc, magnesium); no dairy (calcium); no liver and small fish (zinc, calcium, magnesium); no meat/poultry/fish (zinc); and no meat/poultry/fish/eggs (zinc, vitamin B12).

Food patterns with monotonous staple foods remained low in iron and also introduced new gaps, as follows: root/tubers only (zinc, magnesium); whole-grain white maize only, and also white rice only (calcium, potassium, zinc, magnesium).

Increasing the quantity of staple foods from 3.5 to 7, 14 and 17 daily servings per week introduced progressively more nutrient gaps. At 17 daily servings, the food pattern included only breast milk and starchy staples foods, and in addition to gaps for iron (12% of NRV) and vitamin D (0%) there were gaps for: calcium, potassium, zinc, thiamin, riboflavin, choline, vitamin B6, copper, and magnesium.

Food patterns that included unhealthy items had new gaps for minerals and B vitamins even when these items were included only one day a week. Gaps increased when the items were included three or seven days a week. When sweet biscuits were included seven days a week all other complementary food was displaced, and gaps were similar to those in the scenario with staple foods maximized.

In summary, to meet target and other nutrient needs from an unfortified food supply, breastfed infants in this age group require diverse diets with daily animal-source protein foods of specific types, ample and diverse vegetables, very limited amounts of staple foods, and no refined grains or unhealthy items. Even in the liberalized best-case scenario, with beef and liver allowed seven days a week, iron needs could not be met.

Adding fortified products designed for IYC either as one, three or seven daily servings per week had varying effects on nutrient gaps, given differing levels of fortificants and of energy. MNPs are non-caloric, whereas a 20-gram daily serving of SQ-LNS (one sachet) provides 118 kilocalories and a 35-gram daily serving of Super Cereal Plus provides 144 kilocalories.

Inclusion of any of the fortified items eliminated the gap for carbohydrate and substantially reduced the gap for vitamin D; however, vitamin D remained at only 39-52% of the NRV even when fortified items were consumed daily. Other impacts varied by product.

Inclusion of daily MNPs eliminated the iron gap. In this scenario, there was a new gap for the non-target nutrient magnesium. This is because once all targets were met, Optifood minimized protein and this had the effect of creating a gap. Unlike the feasible best-case food pattern, the pattern with daily MNPs had no whole grains or legumes, both of which are rich in magnesium. Further iteration could provide solutions that addressed this gap while also still meeting target nutrient needs.

Inclusion of daily SQ-LNS substantially reduced but did not eliminate the iron gap (59% of NRV, compared to 28% of NRV in the feasible best-case scenario). Like daily MNP, the scenario for daily SQ-LNS had a gap for the non-target nutrient magnesium, but it also had gaps for the target nutrients potassium (76% of NRV) and choline (82% of NRV). This scenario also exceeded the UL for zinc. Further iteration would be required to try to avoid excesses and close gaps. However, it is not clear that this would be possible unless staple foods were entirely eliminated, because in this scenario SQ-LNS displaced all other complementary foods.

Daily servings of Super Cereal Plus *increased* the nutrient gap for iron and created substantial new gaps for several minerals, thiamin and choline, again because Super Cereal Plus displaced other foods that provided these nutrients.

Models with fortified items also provide insight into whether lower quality, less costly food patterns can meet needs, so long as fortified items are included. When MNPs were given daily, the food pattern included the minimum amount of starchy staple foods (roots/tubers), a very small amount of egg (less than one a week), ample and diverse vegetables, and a daily serving of 60 g (one-quarter cup) of fluid milk. Most nutrient needs could be met without flesh foods, but not without vegetables and dairy; as noted iteration could address the issue of low magnesium.

For SQ-LNS and Super Cereal Plus, food patterns were monotonous due to the level of displacement. The patterns consisted almost entirely of breast milk, the fortified item, and, in the case of SQ-LNS, the minimum required amount of staple foods. These food patterns did not meet all target nutrient needs, and it is unlikely that they could, without reducing the proportion of breast milk and increasing the ‘space’ for other complementary foods.

4.3.2. Modifying food patterns for breastfed infants 9-11.9 months of age

For this age group, modifying food patterns by eliminating food groups, restricting staples to one type, increasing the quantity of staples, or introducing unhealthy items had little impact on nutrient gaps. The gap for iron was somewhat increased under many of these scenarios, but no new gaps were introduced except for a small gap for fat when staple foods were increased to 21 servings per week.

It appears that except for iron and vitamin D, there are many food patterns that can meet nutrient needs for this age group so long as a diversity of whole grain foods, fruits, vegetables and protein foods are available and included. Inclusion of one unhealthy item per day did not create nutrient gaps. We note that we did not model scenarios with multiple unhealthy items per day.

As for the younger infants, inclusion of any of the fortified items eliminated the gap for carbohydrate and substantially reduced the gap for vitamin D; however, vitamin D remained at only 43-54% of the NRV, when fortified items were consumed daily. Other impacts varied by product. For this age group, food patterns with Super Cereal Plus did not introduce new nutrient gaps, but also did not reduce the gap for iron.

MNPs three days a week or SQ-LNS seven days a week improved iron values to 80-85% of NRVs. MNPs seven days a week eliminated the gap for iron. For this age group, scenarios with daily SQ-LNS did not result in any new gaps for target nutrients. The food patterns with either MNPs or SQ-LNS, either three or seven days a week, all exceeded the UL for zinc. Further iteration would be required to try to avoid excesses.

Compared to the feasible best-case pattern, food patterns with daily MNPs had more fruit, dairy and added fats/oils, and fewer vegetables and particularly fewer protein foods. In this scenario with daily MNP, iron needs were met without inclusion of flesh foods or plant-source protein foods; the scenario included about one egg a week and a daily serving of about one-quarter cup of milk. Vegetables, though reduced, were still ample, and the food pattern remained diverse overall.

In the food pattern with daily SQ-LNS, starchy staple foods were reduced to the minimum amount allowed and there were no fruits or dairy. This food pattern had fewer vegetables than the best-case pattern, but protein foods were similar, with liver, small fish, legumes and soy foods all selected at the maximum allowable amount, likely because iron needs were not met.

In the food pattern with Super Cereal Plus seven days a week, there were fewer servings of whole grain foods, fruits and legumes, but vegetables remained ample and diverse, and soy foods, liver and small fish were all selected at the maximum allowable amount, likely because iron needs were not met.

In sum, for breastfed infants 9-11.9 months of age, only MNPs could close iron gaps and meet target nutrient needs with minimal protein foods. However, meeting all targets required a small amount of dairy and ample fruits and vegetables. Since the other fortified items did not close the iron gap, the food patterns with daily SQ-LNS or daily Super Cereal Plus remained diversified, including diverse vegetable and protein-food subgroups, but no dairy and little or no fruit.

4.3.3. Modifying food patterns for breastfed children 12-23.9 months of age

For breastfed children 12-23.9 months of age feasible best-case patterns had no gaps for target nutrients. For this group, certain scenarios that eliminated food groups introduced new nutrient gaps.

Scenarios with no vegetables or no animal-source protein foods introduced iron gaps (88-94% of NRV). The scenario with no animal-source protein foods introduced a small gap for vitamin B12 (95% of NRV), and the scenario with no fruits or vegetables introduced a small gap for fiber (96% of NRV; non-target). Scenarios with monotonous staple foods, or with increased quantities of staple foods did not introduce new nutrient gaps. The scenarios with no whole grains or only roots/tubers/plantains slightly exceeded the UL for copper.

Inclusion of sweetened beverages seven days a week introduced a small gap for thiamin, but no other new gaps were introduced with inclusion of a single unhealthy item consumed up to seven days a week, so long as a diversity of whole grain foods, fruits, vegetables, and protein foods are available and included in food patterns. As noted for infants, we did not model combinations of unhealthy items on the same day.

Inclusion of any of the fortified products eliminated the gap for carbohydrate and reduced the gap for vitamin D. Scenarios with Super Cereal Plus, included up to seven days per week, did not have any other nutrient gaps; this was also true of the best-case scenario with no fortified products.

When included three or seven days per week, scenarios with MNPs had a gap for the non-target nutrient phosphorus (84% and 73% of NRV, respectively), for reasons explained above. That is, since all target nutrients were met, Optifood minimized protein, and many protein-rich foods are also rich in phosphorus. At seven days a week, the food pattern also slightly exceeded the UL for copper. Further iteration could likely address excesses and gaps.

At either three or seven days per week, scenarios with SQ-LNS had also gaps for phosphorus (82% and 75% of NRV, respectively) and at seven days per week the scenario had gaps for fiber (80% of NRV) and a small gap for vitamin B12 (97% of NRV). This scenario also exceeded the UL for zinc. Further iteration could likely address excesses and gaps, because unlike in the scenarios for the youngest age group, daily SQ-LNS displaces only one-quarter of the energy available for complementary foods and beverages.

In the food patterns with MNPs or SQ-LNS seven days a week, staple foods were reduced to the minimum allowed, fruits were increased, vegetables were decreased in quantity and variety, protein foods were eliminated (MNP) or nearly eliminated (SQ-LNS) and added fats/oils were increased to the maximum allowed amount. Dairy foods were increased for the MNP scenario but eliminated with daily SQ-LNS, likely reflecting the difference in calcium content of the two items.

The scenario with daily Super Cereal Plus had less whole grain and more roots/tubers. It had no fish but included the same amount of liver and soy foods as the best-case scenario. Also like the best-case scenario, the scenario with daily Super Cereal Plus included ample and diverse fruits and vegetables.

For non-breastfed children 12-23.9 months of age, target nutrient needs could be met without fortified products. The scenarios with fortified products were somewhat less diverse. They had fewer servings per week of whole grain foods and of flesh foods and, except for MNPs, fewer servings of dairy, indicating a possible role for fortified items in settings where such foods are unavailable. However, even scenarios with daily fortified products continued to include three to five types of fruits and vegetables daily.

In sensitivity analyses excluding flesh foods and assuming 5% absorption of iron, daily MNPs eliminated a gap for iron and SQ-LNS reduced but did not eliminate it. Super Cereal Plus did not reduce the gap.

4.3.4. Modifying food patterns for non-breastfed children 12-23.9 months of age

For non-breastfed children 12-23.9 months of age feasible best-case patterns had gaps only for carbohydrate and vitamin D, and no gaps for target nutrients. For this group, certain scenarios that eliminated food groups introduced new nutrient gaps.

Scenarios with no fruits or vegetables were low in vitamin C (81% of NRV) and there was a small gap for the non-target nutrient linoleic acid (95%). Scenarios with no flesh foods or no animal source protein foods were low in vitamin B12 (~92% of the NRV).

Restricting the variety of starchy staple foods did not introduce new nutrient gaps so long as a diversity of fruits, vegetables, and protein foods are available and included. Allowing one sentinel unhealthy item up to seven day a week also did not introduce new nutrient gaps; we did not model scenarios with multiple types of unhealthy items.

Many of the modified scenarios for this group slightly exceeded the UL for copper.

Inclusion of any of the fortified products eliminated the gap for carbohydrate and reduced the gap for vitamin D, and none of the fortified products created new nutrient gaps. The scenario with daily SQ-LNS exceeded the UL for zinc, and several of the scenarios with each type of product slightly exceeded the UL for copper. Further iteration would be required to try to avoid excesses.

As for the same-age breastfed children, food patterns that included fortified products seven days a week were somewhat less diverse than the feasible best-case food pattern. They included fewer servings of whole grain foods and no flesh foods, but more eggs (one to three per week) than the best-case scenario with no fortified items. Dairy was increased with daily MNPs but reduced to near zero with daily SQ-LNS or Super Cereal Plus. Also as for the same-age breastfed children, there were diverse fruits and vegetables, averaging four to seven types per day.

In sensitivity analyses excluding flesh foods and assuming 5% absorption of iron, both daily MNPs and daily SQ-LNS eliminated a gap for iron. Super Cereal Plus slightly reduced the gap.

4.4. What are the nutrient gaps when we approximate real-world food patterns?

We approximated real-world food patterns by using available data to characterize population-level patterns for percent of energy from food subgroups in three low- or middle-income settings: rural Bangladesh, rural southern Malawi, and Mexico.

In these population-level food patterns, the percent of energy from the major food groups differed substantially from our modeled best-case scenarios. The calculated nutrient content of these food patterns fell short of target values for most nutrients in one or more settings. Nutrient targets were met in all cases only for protein, fatty acids, vitamins A and C, and niacin.

In Bangladesh and Malawi there were gaps for choline and for most B vitamins and minerals, for all age groups. There were fewer gaps in Mexico, particularly for the oldest age group, but gaps remained for several B vitamins and minerals. As in the modeled scenarios, carbohydrate was low and vitamin D was very low, at 0-9% of the NRV across all three settings. Given the variety and size of the nutrient gaps, inclusion of fortified items provided only a partial solution.

All three fortified items filled gaps for some or all B vitamins. MNPs and SQ-LNS eliminated gaps for zinc and copper, and SQ-LNS reduced or eliminated the gap for calcium. In Bangladesh and Malawi gaps for choline and potassium remained, as did gaps for magnesium and phosphorus for some age groups.

As in the modeling, iron gaps were filled or reduced to the greatest extent by MNPs, followed by SQ-LNS, with Super Cereal Plus having a much smaller impact. However, particularly when assuming lower absorption, iron gaps remained and were very large in some scenarios. In general, MNPs and SQ-LNS appeared to have more positive impacts than Super Cereal Plus. However, nutrient gaps remained in all three settings.

4.5. Strengths and limitations

4.5.1. Strengths

We collated data or other information from surveys or studies in 37 countries, representing many geographic areas and all country income levels. This allowed us to develop a reasonably comprehensive list of food items consumed by IYC as a basis for developing food subgroup nutrient profiles.

Food subgroups were defined and revised as needed to yield a final set of subgroup profiles that differed in meaningful ways. We aimed for subgroups that were narrow enough to be nutritionally distinguishable, but sufficiently broad to be relevant for discussions of recommendations.

We analyzed quantitative 24-hour recall data from 16 countries to develop modeling parameters for quantities and frequencies of consumption for food groups and subgroups. The 16 countries included low-, middle- and high-income countries, and countries in Africa, Asia, Europe, Latin America, and North America.

We modeled using optimization software that was developed to meet objectives very similar to our own, and the software was sufficiently flexible to address all the questions of interest. We modeled a large number of scenarios, which allowed us to understand main themes in the results.

4.5.2. Limitations

Our work also had important limitations, related to:

1. Data sources
2. Food item lists and food subgroups
3. Food composition data
4. Nutrient profiles
5. Absorption of minerals
6. Modeling at the subgroup rather than the food item level
7. Scenarios we did not model

Data sources

Although we made a major effort, data are not globally representative. Some global regions are underrepresented, and data for some countries are from small local or regional studies. Data are also heterogeneous (methodology, formats, etc.); however we developed approaches to dealing with this heterogeneity as described in the Annexes. In addition, all quantitative 24-hour recall data are inherently imprecise and can be biased.

Food item list and food subgroups

For our global list we excluded items and subgroups that were rarely consumed in most or all of the countries for which we had data. But some of these items can be important nationally or locally, including non-liver organ meats, seafood, snails, and insects. There are also a variety of wild and foraged fruits and vegetables that may be nutrient-dense. Where available and acceptable, they should be included in analyses supporting development of national or local food-based recommendations.

Food composition data

For practical reasons, we selected the US food composition databases as our primary sources, though nutrient composition for many foods varies geographically.

For nutrient composition of breast milk, we used values from the USDA food pattern modeling report (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020). However, this source did not include values for DHA and EPA. Values for DHA and EPA in our primary sources are zero, which we questioned. Though we had initially planned to, we chose to not report results for DHA and EPA, which were not target nutrients.

Data on linoleic acid and α-linolenic acid were not available for many foods. When they were not available, we used data on undifferentiated 18:2 and 18:3 fatty acids, so nutrient profiles for these two nutrients could be slightly biased (high). We judge that this was unlikely to have substantially impacted the results.

We had particular challenges with matching fish to food composition data, because fish are often poorly described in dietary data sets. Also, some common names for fish can refer to a wide variety of species.

Nutrient profiles

When developing nutrient profiles, it is ideal if individual food items can be weighted based on their relative percent contribution to total consumption of the food subgroup. This takes into account both frequency of consumption and amounts consumed. For this type of weighting, we would have needed globally representative dietary data for IYC.

Lacking such data, we instead weighted based on the proportion of countries in which each item was reported to be consumed by IYC. This ensured that items that were commonly consumed across many geographies were more heavily weighted, and those that were reported in few countries were less heavily weighted. But we do not know how our weighting would compare to the ideal.

Second, although we reviewed distributions of nutrients within food subgroups and excluded some outlier items (true outliers as well as suspect values), several subgroups (particularly those with a small number of items) have heterogeneity in certain nutrients, making the subgroup profile less meaningful. Specifically:

- For some grains subgroups, inclusion of nixtamalized maize products pulled up calcium values slightly; however, the number of items in these subgroups was not extremely small, and the nutrient profiles were not strongly affected.
- Among the few high-fat fruits, avocado is high in folate and coconut is high in iron, which affected the nutrient profile. Fresh coconut may also be eaten in smaller quantities than avocado, yet we created a median serving size for both foods based on higher observed medians, which may have been more appropriate for avocado.
- For soy foods, we used the same representative item for tofu as did the USDA in their food pattern modeling exercise for IYC, and it is a type coagulated with calcium and magnesium salts; this affected the subgroup nutrient profile.
- For fish (both small and large fish subgroups) there is very high true variability for some nutrients. Further, for the food subgroup of small fish eaten with bones we included several species that are available in global markets, but we also included several that are specific to Eastern and Southern Africa, yielding uneven geographic representation in the subgroup.

Absorption of minerals

For several problem nutrients, especially calcium, iron and zinc, there are dietary and non-dietary influences on absorption. It was not possible for us to take a nuanced approach, accounting for enhancers and inhibitors of absorption and other factors.

We accepted the assumptions about nutrient absorption inherent to the selected NRVs, on the principle that our models allowed ample amounts of all food subgroups, thus food patterns in solutions could resemble mixed diets as in the reference value documents. However, for scenarios for children 12-23.9 months of age this led to food patterns with minimal flesh foods, because Optifood minimizes protein as a proxy for cost once all nutrient targets are met. We addressed this by performing sensitivity analyses assuming a lower absorption level for iron.

Modeling at the subgroup rather than the food item level

By using subgroup nutrient profiles, we were modeling food subgroups 'at the mean'. That is, the profiles were developed as weighted averages of sets of food items, and our modeling did not explore the nutrient variability within each subgroup, nor how choices within food subgroups would affect nutrient gaps.

The Optifood software has a module that addresses this issue of variability, but it was not feasible for us to explore this. This means that our results should be interpreted cautiously, and with an understanding that they provide a general picture but have inherent false precision.

Scenarios we did not model

Although we modeled a large number of scenarios, for reasons of time and cost we could not model all desirable scenarios. The most important limitations were:

- We assumed the same proportion of energy from breast milk for all IYC in a given age group; modeling for multiple proportions would have been desirable;
- We did not model mixed feeding with breast milk and formula;
- We modeled best-case food patterns at three energy levels for each age/feeding group, but we restricted modeling of the various modifications to one energy level for each age group, based on the EER for an average-sized child at the mid-point of the age range;
- We did not model a number of plausible scenarios, including:
    - Eliminating additional combinations of food subgroups, such as both whole grains and flesh foods at the same time;
    - Simultaneously eliminating food subgroups that were relatively rarely consumed, such as berries, high-fat fruits, soy foods, liver, and small fish with bones;
    - Increasing staple foods while also restricting to one type of staple food;
    - Including multiple types of sentinel unhealthy foods at the same time;
    - Including sentinel unhealthy foods while also eliminating various nutrient-dense food groups.

Any of these 'combination' scenarios could cause more numerous or deeper gaps in target and non-target nutrients. The scenarios approximating real-world patterns embodied some of these combinations.

4.6. Summary of key results

Our analyses allowed us to comment on the following questions:

- Can target nutrient needs be met with unfortified best-case food patterns?
- What happens when food groups or subgroups are eliminated?
- What happens when staple foods are monotonous?
- What happens if we modify the amount of starchy staple foods?
- What happens if we add unhealthy foods or beverages?
- What are the nutrient gaps when we approximate real-world food patterns?
- Can fortified items fill all nutrient gaps?

Note that our use of the Optifood software did not produce specific food-based recommendations, but rather has provided general answers to the questions above. There are several reasons why the food patterns in our solutions should not be regarded as food-based recommendations, and some of these were noted among the limitations above. In particular, we noted that the process of using Optifood to develop recommendations includes additional steps to explore the variability in nutrient gaps that results from variability within the food subgroups.

In addition, the nature of optimization means that certain food subgroups will be consistently selected and others not (for example, beef rather than pork or poultry, small fish rather than larger fish, etc.). Yet some of the subgroups that were not selected or were rarely selected are nutrient-dense and can be part of healthy and nutrient-sufficient diets. The modeling is highly sensitive to all parameters, including NRVs and selection of target nutrients; different selections for either of these could yield different selections of food subgroups in the model solutions.

Further, development of food-based recommendations generally takes into account existing food patterns and food supplies, so that recommended changes may be sufficiently incremental and acceptable. The best-case food patterns described here, rich in whole grains and vegetables, are very different from many existing food patterns. Also, for non-breastfed children 12-23.9 months of age, Optifood's second objective – to minimize protein when nutrient targets are met – resulted in best-case food patterns that may be unpalatably high in whole grain starchy staple foods.

Finally, use of optimization in development of food-based recommendations nearly always includes significant iteration to fine-tune solutions. As we noted, many of our model solutions could be further iterated to address gaps for non-target nutrients and to avoid exceeding AMDRs or ULs.

For all these reasons, our results should be interpreted as providing general answers to the questions we have identified, rather than specific food patterns to be promoted. In answer to the questions, we find:

- **Can target nutrient needs be met with unfortified best-case food patterns?**
  Except for the smallest infants in the youngest age group, unfortified foods consumed in feasible amounts can meet all target nutrient needs except for iron in infancy. However, this requires availability of and financial access to diverse foods from all food groups and also requires consumption of diverse vegetable and protein food subgroups.
- **What happens when food groups or subgroups are eliminated?**
  For infants 6-8.9 months of age, eliminating whole grains, vegetables or various protein food subgroups resulted in numerous nutrient gaps. For infants 9-11.9 months of age, there were no additional gaps for target nutrients, though the iron gap was increased under some scenarios. For children 12-23.9 months of age there were gaps for iron, vitamin B12, or vitamin C under some scenarios. Elimination of all fruits and vegetables, all flesh foods, or all animal-source foods more broadly was most problematic for older IYC.
- **What happens when staple foods are monotonous, and what happens when staple foods are increased in quantity?**
  Restricting the type or increasing the amount of staple foods also caused multiple nutrient gaps for the youngest age group. It did not introduce additional nutrient gaps for older IYC when food patterns included the diverse nutrient-dense foods available in the best-case scenarios.
- **What happens if we add unhealthy foods or beverages?**
  Results were similar for sentinel unhealthy items – there was no space for these in the diets of 6-8.9 month old infants, but there was space in the diets of older IYC for daily serving, when food patterns also included diverse nutrient-dense foods.
- **What are the nutrient gaps when we approximate real-world food patterns?**
  There were gaps for B vitamins, choline and minerals in all three settings, with more numerous and larger gaps in Bangladesh and Malawi. Gaps were larger than those in model solutions.

- **Can fortified items fill all nutrient gaps?**
  Fortified items had diverse impacts related to their composition and energy content per dose, which resulted in varying patterns of displacement. For the youngest infants, SQ-LNS and Super Cereal Plus displaced all or most food, other than breastmilk, resulting in nutrient gaps.

  For modeled food patterns, all products reduced gaps for vitamin D. Super Cereal Plus did not provide other benefits. MNPs and SQ-LNS reduced or eliminated gaps for iron.

  For real-world food patterns, all three fortified items reduced or eliminated gaps for B vitamins and for iron; results for iron were best with MNPs, followed by SQ-LNS. MNPs and SQ-LNS eliminated gaps for zinc and copper, and SQ-LNS reduced or eliminated the gap for calcium. There were remaining nutrient gaps in each setting.

We conclude that except for iron, and except for the smallest infants, it is possible to meet all target nutrient needs from unfortified foods consumed in feasible quantities. However, the best-case food patterns that achieved this are very different from those found in many real-world settings.

For the youngest infants, the best-case food patterns include very small amounts of starchy staple foods. For all IYC the best-case patterns are rich in diverse vegetables, include flesh foods, and exclude refined grains.

Several examples approximating real-world food patterns had a lower percent of energy from vegetables and protein foods, and there were numerous nutrient gaps. Fortified items provided only a partial solution.

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Annex 1 Calculation of estimated energy requirements

For age intervals of 6-8.9, 9-11.9 and 12-23.9 months, the US/Canadian DRI (Institute of Medicine 2005a) estimated energy requirements (EER) are based on a formula derived from total energy expenditure (TEE) measured by doubly-labeled water, plus a set amount for growth (energy deposition):

EER for Ages 0 Through 36 Months

EER = TEE + energy deposition
0–3 months (89 × weight [kg] – 100) + 175 kcal
4–6 months (89 × weight [kg] – 100) + 56 kcal
7–12 months (89 × weight [kg] – 100) + 22 kcal
13–36 months (89 × weight [kg] – 100) + 20 kcal

The median weights of boys and girls (averaged together) from the WHO Child Growth Standards at the midpoint of each range (7.5, 10.5 and 18 mo) are 8.1 kg, 9.0 kg and 10.6 kg (see tables at https://www.who.int/tools/child-growth-standards/standards/weight-for-age). We used these median weights in the formulas above, to yield EER (**Table A1.1**).

In addition to modeling for energy intakes based on median body weights, we also modeled for smaller and larger children within each age range, yielding lower and higher EER as follows:

- Lower levels: the EER was calculated for girls at the low end of the age range and at the 25th percentile for weight-for-age
- Higher levels: the EER calculated for boys at the top end of the age range and at the 75th percentile for weight-for age

Table A1.1 presents three EER for each age subgroup.

Table A1. 1 Estimated energy requirements (EER) for children of varying size in 3 age groups

6-8.9 mo		**Kg**	**EER**
Low	Weight of girl at 6 mo, 25th percentile	6.7	518
Middle	Average weight of boys/girls at 7.5 mo, 50th percentile	8.1	643
High	Weight of boy at 9 mo, 75th percentile	9.6	776
9-11.9 mo			
Low	Weight of girl at 9 mo, 25th percentile	7.6	598
Middle	Average weight of boys/girls at 10.5 mo, 50th percentile	9.0	723
High	Weight of boy at 12 mo, 75th percentile	10.4	848
12-23.9 mo			
Low	Weight of girl at 12 mo, 25th percentile	8.2	650
Middle	Average weight of boys/girls at 18 mo, 50th percentile	10.6	863
High	Weight of boy at 24 mo, 75th percentile	13.1	1086

Annex 2 Selection of nutrient reference values

We selected Nutrient Reference Values (NRVs) either from the Dietary Reference Intakes (DRIs) of the US and Canada (National Academies of Sciences, Engineering, and Medicine (NASEM) 2019) or from the Dietary Reference Values (DRVs) of the European Food Safety Authority (EFSA 2017).

In deciding whether to select NASEM or EFSA values for specific nutrients, we used the same approach as Allen, Carriquiry, and Murphy (2020) when developing harmonized NRVs for average requirements (AR) and tolerable upper levels of intake (UL). That is:

- We preferred Recommended Dietary Allowances (RDAs, NASEM) or Population Reference Intakes (PRIs, EFSA) to Adequate Intakes (AIs, both NASEM and EFSA) and preferred more recent over less recent NRVs.
- We selected the EFSA PRI or AI values for 5 vitamins (vitamin A, riboflavin, vitamin B6, folate, and vitamin C), choline, and 3 minerals (calcium, iron, and zinc) because EFSA developed the PRI and AI values for these more recently than NASEM developed the equivalent DRI (RDA and AI) values. Similarly, we selected the EFSA PRI/AI/RI for protein, fat, and α-linolenic acid because they are more recent.
- We selected the NASEM RDA or AI values for 3 vitamins (thiamin, niacin, vitamin B12) because EFSA did not develop PRIs for these nutrients.
- For potassium, we made an exception to our decision rule. Both NASEM and EFSA have AI for potassium, and the NASEM values are more recent. However, for 12-23.9 months, they are based only on observed intakes in North America. The EFSA AI are scaled down from adult values intended to minimize risk of hypertension. Further, the NASEM values vary widely by age with an AI of 860 mg/d for infants and an AI of 2000 mg/d for 12-23.9 months. The high value for 12-23.9 months could cause anomalous modeling results. The EFSA AI of 750 mg/d for infants and 800 mg/d for 12-23.9 months were therefore selected for our modeling exercise.

Table A2.1 presents both sets of values, for comparison, and indicates the selected value for each target nutrient. **Table A2.2** presents both sets of NRVs for the non-target nutrients that are reported, and again indicates the selected values.

These tables are followed by an explanation of how we calculated NRVs for protein; notes on absorption of minerals and on units for certain nutrients, and finally by ULs for both target and other reported nutrients.

Table A2.1 Nutrient reference values for use in developing nutrient targets for modeling[a]

	Infants 6-11.9 months of age				Children 1-3 years of age			
	DRI[b]		EFSA[c]		DRI[b]		EFSA[c]	
		Notes		Notes	M/F	Notes		Notes
Fat (g/d)	30	AI	---	---	---	---	---	---
Fat (% energy)	---	---	**40**	**AI**	30-40	AMDR	**35-40**	**RI**
Vitamin A (µg RE/d)	500	AI	**250**	**PRI**	300	RDA	**250**	**PRI**
Thiamin (mg/d)	**0.3**	**AI**	0.1 mg/MJ	PRI	**0.5**	**RDA**	0.1 mg/MJ	PRI
Riboflavin (mg/d)	0.4	AI	**0.4**	**AI**	0.5	RDA	**0.6**	**PRI**
Vitamin B6 (mg/d)	0.3	AI	**0.3**	**AI**	0.5	RDA	**0.6**	**PRI**
Folate (µg DFE/d)	80	AI	**80**	**AI**	150	RDA	**120**	**PRI**
Choline (mg/d)	125	AI	**160**	**AI**	150	AI	**140**	**AI**
Vitamin B12 (µg/d)	**0.5**	**AI**	1.5	AI	**0.9**	**RDA**	1.5	AI
Vitamin C (mg/d)	50	AI	**20**	**PRI**	15	RDA	**20**	**PRI**
Calcium (mg/d)	260	AI	**280**	**AI[d]**	700	RDA	**450**	**PRI[d]**
Iron (mg/d)	11	RDA	**11**	**PRI[e]**	7	RDA	**7**	**PRI[e]**
Potassium (mg/d)	860	AI	**750**	**AI**	2,000	AI	**800**	**AI**
Zinc (mg/d)	3	RDA	**2.9**	**PRI[f]**	3	RDA	**4.3**	**PRI[f]**

[a] Bolded values in cells with no highlighting are selected values. AI = Adequate Intake; AMDR = Acceptable Macronutrient Distribution Range; PRI = Population Reference Intake; RDA = Recommended Dietary Allowance; RI = Reference Intake range.

[b] Values are obtained from the US/Canadian Dietary Reference Intakes (DRIs) (National Academies of Sciences, Engineering, and Medicine 2019).

[c] Values are obtained from the European Food Safety Authority (EFSA) Dietary Reference Values (DRVs) (EFSA 2017).

[d] The EFSA AI for calcium for 6-11.9 month-old infants assumes 60% absorption, based on absorption levels among exclusively breastfed infants (EFSA 2017, p. 25). For the PRI for children 1-3 years of age, 45.6% absorption is assumed (EFSA 2015, p.27).

[e] The EFSA PRIs for iron assume 10% absorption for both age groups (EFSA 2017, p. 33).

[f] The EFSA PRIs for zinc assume 30% absorption from a mixed diet for both age groups (EFSA 2017, p. 45); '*The fractional absorption of zinc considered in setting PRIs for children was based on data from mixed diets expected to contain variable quantities of phytate; therefore, no adjustment for phytate intake has been made*.' (p. 48).

Table A2.2 Nutrient reference values for use in comparing levels of non-target nutrients in modeling results[a]

	Infants 6-11.9 months of age				Children 1-3 years of age			
	DRI[b]		EFSA[c]		DRI[b]		EFSA[c]	
		Notes		Notes	M/F	Notes		Notes
Protein (g/kg/d)[d]	**See below**		See below		**See below**		See below	
Protein (% energy)	---	---			**5-20**	AMDR		
Carbohydrate (g/d)	**95**	**AI**	---	---	**130**	**RDA**	---	---
Carbohydrate (% energy)	---	---	---	---	**45-65**	AMDR	45-60	RI
Linoleic acid (g/d)	4.6	AI	---	---	7	AI	---	---
Linoleic acid (% energy)	---	---	**4**	**AI**	---	---	**4**	**AI**
n-6 PUFA (% energy)[e]	---	---	---	---	5-10	AMDR	---	---
α-linolenic acid (g/d)	0.5	AI	---	---	0.7	AI	---	---
α-linolenic acid (% energy)	---	---	**0.5**	**AI**	---	---	**0.5**	**AI**
n-3 PUFA (% energy)[f]	---	---	---	---	0.6-1.2	AMDR	---	---
Total fiber (g/d)	---	---	---	---	19	AI	**10**	**AI**
Niacin (mg NE/d)[g]	4	AI	---	---	6	RDA	---	---
Niacin equivalents (mg NE)/MJ	---	---	**1.6 NE/MJ**	**PRI**	---	---	**1.6 NE/MJ**	**PRI**
Vitamin D (μg/d)[h]	10	RDA	**10**	**AI**	**15**	**RDA**	15	AI
Magnesium (mg/d)	75	AI	**80**	**AI**	**80**	**RDA**	170	AI
Phosphorus (mg/d)	275	AI	**160**	**AI**	**460**	**RDA**	250	AI
Copper (μg/d)	220	AI	**400**	**AI**	**340**	**RDA**	700	AI

[a] AI = Adequate Intake; AMDR = Acceptable Macronutrient Distribution Range; PRI = Population Reference Intake; RDA = Recommended Dietary Allowance; RI = Reference Intake range.

[b] Values are obtained from the US/Canadian Dietary Reference Intakes (DRIs) (National Academies of Sciences, Engineering, and Medicine 2019).

[c] Values are obtained from the European Food Safety Authority (EFSA) Dietary Reference Values (DRVs) (EFSA 2017).

[d] RDA and PRI are based on g protein per kg of body weight for a reference body weight. See below for calculations for our reference body weights.

[e] AMDR is for 'n-6 polyunsaturated acids (linoleic acid)' with a note that approximately 10 percent of total can come from longer chain n-6 fatty acids.

[f] AMDR is for 'n-3 polyunsaturated acids (α-linolenic acid)' with a note that approximately 10 percent of total can come from longer chain n-3 fatty acids.

[g] Niacin equivalents (NE): 1 mg niacin = 60 mg tryptophan.

[h] As cholecalciferol. 1 μg cholecalciferol = 40 IU vitamin D; 0.025 μg = 1 IU. Reference values under assumption of minimal sunlight.

Nutrient reference values for protein

In both sets of NRVs, values for protein are based on reference body weights, multiplied by a factor for grams protein/kg body weight/day. Values are RDAs (NASEM DRIs) and PRIs (EFSA NRVs).

For the DRIs, we back-calculated the factor from the RDAs for protein for each age range (National Academies of Sciences, Engineering, and Medicine 2019) and the reference body weights referred to in that document (Institute of Medicine 2005a). Note, however, that the reference body weight is stated as for 7-12 months, while the RDA is stated as for 6-12 months.

For the EFSA PRIs, factors are given for age points 0.5 year, 1.0 year, and 1.5 years. After discussion with the GDG we used linear interpolation to derive factors for 6-8.9 months and 9-11.9 months and used the factor for 1.5 years for the age range 12-23.9 months.

Table A2.3 Calculations to derive factors for grams protein/kg/g[a]

DRI				EFSA		Interpolated factor	
Age range	**RDA**	**Kg**	**g/kg/d**	**Age**	**g/kg/d**	**Age range**	**g/kg/d**
6-12 mo	11	9	1.22	0.5 y	1.31	6-8.9 mo	1.27
				1.0 y	1.14	9-11.9 mo	1.18
1-3 y	13	12	1.08	1.5 y	1.03	12-23.9 mo	1.03

[a] Sources: RDAs: National Academies of Sciences, Engineering, and Medicine 2019, p. 572; DRI reference body weights: Institute of Medicine 2005, p. 35; EFSA factors per age point: EFSA European Food Safety Authority 2017, p. 24.

For deriving our protein targets, we used these factors and the same 9 body weights used in our calculation of EER, above. As for other NRVs, the two sets are presented for comparison, with the selected values bolded.

Table A2.4 Protein reference values (g/d) by age group/body weight using DRI and EFSA factors[a]

	kg	**DRI**	**EFSA**
6-8.9 mo			
Low	6.7	8.2	**8.5**
Middle	8.1	9.9	**10.3**
High	9.6	11.7	**12.2**
9-11.9 mo			
Low	7.6	9.3	**9.0**
Middle	9.0	11.0	**10.6**
High	10.4	12.7	**12.3**
12-23.9 mo			
Low	8.2	8.9	**8.4**
Middle	10.6	11.5	**10.9**
High	13.1	14.2	**13.5**

[a] Bolded EFSA values are selected because they are more recent.

Notes on absorption of minerals

NRVs shown in the Table above incorporated assumptions on absorption as detailed in the footnotes and repeated here:

- The EFSA AI for calcium for 6-11.9 months assumes 60% absorption, based on absorption levels among exclusively breastfed infants (EFSA 2017, p. 25). For the PRI for children 1-3 years of age, 45.6% absorption is assumed (EFSA 2015, p.27).
- The EFSA PRIs for iron assume 10% absorption for both age groups (EFSA 2017, p. 33).

- The EFSA PRIs for zinc assume 30% absorption from a mixed diet for both age groups (EFSA 2017, p. 45); '*The fractional absorption of zinc considered in setting PRIs for children was based on data from mixed diets expected to contain variable quantities of phytate; therefore, no adjustment for phytate intake has been made*.' (p. 48).

Because our feasible best-case scenarios for children 12-23.9 months of age met NRVs for all target nutrients Optifood minimized protein, and the resulting scenarios were very low in flesh foods. Because of this, we ran additional models with a modified assumption for absorption of iron of 5%.

Notes on units

Vitamin A
The selected NRVs are from EFSA and are expressed in µg retinol equivalents (RE/d). The US databases that are our primary source for nutrient data provide values for vitamin A in foods as retinol, retinal activity equivalents (RAE), international units (IU) and carotenoids, but not as RE. Attention was paid to converting values, as needed, during development of the food composition database.

Folate
The NRVs are expressed in terms of dietary folate equivalents (DFEs). One DFE = 1 µg food folate. For modeling of supplements or fortificants, µg DFE = µg food folate + (1.7 x µg folic acid) (EFSA 2017, p. 75).

Niacin
The NRVs are expressed in terms of niacin equivalents (NE). One mg of niacin = 60 mg of tryptophan. In addition, the selected NRVs are expressed as NE per MJ energy. **Table A2.5** below shows NRVs for the energy levels selected for modeling (Table 1 and Annex 1 above), based on the EFSA PRI of 1.6 NE/MJ, which holds for both age groups.

Table A2.5 EFSA PRI for niacin equivalents for energy levels used in modeling

	Energy levels		
Age and milk feeding	**Low**	**Median**	**High**
6-8.9 month			
Breastfed	3.5	4.3	5.2
9-11.9 months			
Breastfed	4.0	4.8	5.7
12-23.9 months			
Breastfed	4.4	5.8	7.3
Fed with cow's milk	4.4	5.8	7.3

Tolerable upper intake levels for target nutrients
Tolerable upper intake levels (UL) were not entered as model constraints. That is, model 'solutions' could exceed the ULs. However, for all model solutions that are output, intake levels were compared to ULs and commented on in results reporting. **Table A2.6** below summarizes NASEM and EFSA ULs.

Table A2.6 Tolerable upper intake levels (UL) for target nutrients and other nutrients[a]

	Infants 6-11.9 months of age		Children 1-3 years of age	
	NASEM	EFSA	NASEM	EFSA
Vitamin A (µg/d)	600[b]	Blank	600[b]	800[c]
Thiamin (mg/d)	ND	ND	ND	ND
Riboflavin (mg/d)	ND	ND	ND	ND
Niacin (mg/d)	ND	Blank	10[d]	150 / 2[e]
Vitamin B6 (mg/d)	ND	Blank	30	5
Folic acid (µg/d)	ND	Blank	300[d]	200
Choline (mg/d)	ND	--	1000	--
Vitamin B12 (µg/d)	ND	[f]	ND	[f]
Vitamin C (mg/d)	ND	ND	400	ND
Vitamin D (µg/d)	38	35	63	50
Calcium (mg/d)	1500	ND	2500	ND
Copper (µg/d)	ND	Blank	1000	1000
Iron (mg/d)	40	ND	40	ND
Magnesium (mg/d)	ND	Blank	65[g]	[h]
Phosphorus (g/d)	ND	Blank	3	ND
Potassium (mg/d)	--	ND	--	ND
Zinc (mg/d)	5	Blank	7	7

[a] Sources: EFSA https://www.efsa.europa.eu/sites/default/files/assets/UL_Summary_tables.pdf. *Overview on Tolerable Upper Intake Levels as derived by the Scientific Committee on Food (SCF) and the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA).* Version 4 September 2018, and summary tables for DRI in: National Academies of Sciences, Engineering, and Medicine 2019. *Dietary Reference Intakes for Sodium and Potassium.* National Academies: Washington, DC.

ND = Not determinable/no adequate data to derive a UL. 'Blank' indicates nutrient is present in the source table, but the cell is blank. '—' indicates the nutrient is not included in the source table.

[b] As preformed vitamin A only.

[c] Retinol and retinyl esters.

[d] The ULs for niacin and folic acid apply to synthetic forms obtained from supplements, fortified foods, or a combination of the two.

[e] The two values are for nicotinamide (150 mg) and nicotinic acid (2 mg), respectively.

[f] For Vitamin B12, EFSA indicates 'no clearly defined adverse effects'.

[g] The US/Canadian ULs for magnesium are for intake from pharmacologic agents only and not from food and water.

[h] For magnesium, EFSA indicates 'insufficient data' and notes that the UL does not include magnesium naturally present in foods and beverages.

Annex 3 Detailed description of food subgroups

This Annex provides a detailed description of food subgroups. We first describe types of items that are excluded from food subgroups. This is followed by a set of tables with further operational definitions and notes for each main food group.

Exclusions

The following exclusions were used when developing the food item list. That is, if the food appeared in a data set or country item list, it was excluded and did not contribute to the estimates of subgroup intakes in grams, nor to the subgroup nutrient profile. In some cases, we excluded items because they differed too greatly in water content from most items in the subgroup, and would bias nutrient profiles (for example, dried fruit).

Certain exclusions applied to all food groups:

1. Fortified and enriched food and beverage items were replaced in food item lists with unfortified items. This affected primarily flours, bakery products, breakfast cereals, infant cereals, dairy, and some fats and oils.
2. Condiments were excluded from all food groups; specific examples are included below. Condiments were defined as items generally added in very small quantities to either add flavor to mixed dishes, or as garnishes.
3. Mixed dishes that were not disaggregated in source data into their component parts were excluded. Exceptions to this were:
    a. Certain items with breading or coating. For example, breaded fish or chicken nuggets were included, but the breading was not coded into any food group. When calculating nutrient profiles, plain items (unbreaded) were substituted for the breaded items;
    b. Foods that are mainly one ingredient, and the item would otherwise be unrepresented in the food item list for the data set – for example, 'creamed spinach', if there was no other spinach in the item list from the data set; when calculating nutrient profiles, plain boiled spinach was substituted.
4. Items with vague descriptions that could fit in more than one food subgroup (for example, 'meatball', which could be beef, pork, lamb, etc., or a mix).

Starchy staples

a. Sweetened breakfast cereals, defined as those containing > 15 grams total sugar per 100 grams, which is the cut-off in the WHO Regional Office for Europe nutrient profile model related to marketing to children (WHO Regional Office for Europe 2015).[23]
b. Cakes, cookies/sweet biscuits (excluded from staples, included with unhealthy foods)
c. Breadcrumbs and other coatings
d. Crackers, crispbreads, etc.
e. Grain-based beverages unless there was evidence (that is, percent water back-calculated from intake data) that consistency was similar to porridges
f. Fried foods such as French fries, fried dough, and others (excluded from staples; included with unhealthy foods)

[23] In some cases where a value for total sugar was not available but a value for added sugar was, we used the value for added sugar to assess against the cut-off. Sweetened cereals were excluded because it is possible that they are eaten in larger daily quantities if, for example, eaten as snacks throughout the day, vs. unsweetened cereals. We did not want to upwardly bias quantities for breakfast cereals based on inclusion of sweet cereals.

Fruits

a. Dried fruits
b. Tamarind – very low in water content (similar to values in dried fruit), generally used as a paste, and considered as a condiment
c. Red palm pulp/flesh – does not fit well with other vitamin A-rich fruits due to very high fat content; does not fit well with other high-fat fruits due to very high vitamin A content; eaten only in specific regions
d. Lemon and lime; considered as condiments
e. Fruit desserts, fruit 'leathers' and similar; sweetened fruits were included but matched to unsweetened versions (see below)
f. Juices and smoothies

Vegetables

a. Fresh and dried herbs
b. Chilis (hot peppers)
c. Garlic
d. Pickles
e. Olives

Dairy

a. Very high-fat dairy items such as sweet cream and sour cream
b. Dairy desserts and similar (for example, flan, ice cream, custard)
c. Flavored milks (chocolate, etc.)
d. Certain highly sweetened yogurt drinks with high water and low protein content; however, most sweetened yogurts were included as in many settings all or nearly all yogurt consumed was sweetened; we replaced sweetened yogurts with unsweetened when calculating nutrient profiles
e. Infant formula
f. Other 'milks' – soy milk, almond milk, etc. (that is, non-dairy)
g. Milk in powdered form, except in data sets where <5% of children consumed fluid milk, but >=5% consumed the combination of fluid and powdered milk; when included, we hydrated powdered milk to same water content as fluid milk when estimating quantities and calculating nutrient profiles

Protein foods

a. 'Soy sausage' as this is like a processed meat in its sodium content, and is not similar to tofu, etc.
b. Tempeh and miso, as they do not fit well with soy beans and tofu in water content and quantity consumed; miso may also be more like a condiment (also rarely reported)
c. Chestnuts, as they differ in water, protein, and fat content from other nuts, and do not fit well in any subgroup (also rarely reported)
d. Seeds, when consumed in very small quantities (mean consumption < 5 grams); in these cases they were considered as condiments
e. Processed meat
f. Dried fish were included but either in boiled forms, or, when listed as dried, they were hydrated to similar water levels as in boiled forms when estimating quantities and calculating nutrient profiles
g. All organ meats and all seafood and snails were originally included but they were excluded after review of draft nutrient profiles for the subgroups. Organ meats other than liver and

various seafoods and snails were not consumed or were very rarely consumed in most countries (see **Table A3.1**, next page). These items biased nutrient profiles and were therefore excluded.

h. Insects were excluded. They have been identified as potentially nutrient-rich foods for infants and young children but were never identified as consumed by more than 5% of infants or children in our data sets.

Fats

a. Red palm oil – so as not to distort the nutrient profile of the subgroup of solid/saturated fats

Miscellaneous

These were rarely reported items that did not fit well in any subgroup, and could bias subgroup nutrient profiles:

a. Hog bone marrow
b. Toad meat powder
c. Vegemite/Marmite
d. Mungbean noodles

After review of draft nutrient profiles, we excluded several other rarely consumed items that were nutrient outliers within their respective subgroups:

a. Eel (very high in vitamin A and fat, relative to other fish)
b. Hawthorn fruit (extremely high in vitamin A, and we also were not confident in our food composition match for this item)
c. Egg yolk (high outliers for several nutrients and) were rarely reported to be consumed, and we 'rematched' these items to whole eggs

Tables A3.2 – A3.6 on the following pages provide further details for each broad food group.

Table A3.1 Number of countries where food subgroups were consumed, and where food subgroups were consumed by ≥ 5% infants or young children[a]

	6-11.9 mo	n=8 countries	12-23.9 mo	n=14 countries
Food groups and subgroups	**# countries where consumed**	**# countries where consumed by ≥ 5%**	**# countries where consumed**	**# countries where consumed by ≥ 5%**
Starchy staple foods				
Whole grains	7	5	14	12
Refined grains	8	8	14	14
Whole grain breakfast cereals	6	3	10	5
Refined grain breakfast cereals	7	3	9	3
Whole grain bakery products	6	3	9	6
Refined grain bakery products	8	5	14	13
Starchy roots, tubers, plantains	8	7	14	13
Fruits				
Vitamin A-rich fruits	8	4	14	10
Berries	4	2	8	5
Citrus	8	2	12	6
Vitamin C-rich fruits	6	0	13	2
Bananas	8	6	14	11
High-fat fruits	7	0	11	3
Other fruits	7	5	12	7
Vegetables				
Dark green leafy vegetables	8	3	14	10
Other brassicas	8	5	13	12
Vitamin A-rich orange vegetables	7	5	14	9
Peppers and tomatoes	8	8	14	14
Peas and beans (immature pods)	6	5	11	8
Other vegetables	8	8	14	14

	6-11.9 mo	n=8 countries	12-23.9 mo	n=14 countries
Food groups and subgroups	**# countries where consumed**	**# countries where consumed by ≥ 5%**	**# countries where consumed**	**# countries where consumed by ≥ 5%**
Dairy				
Milk	8	6	14	13
Yogurt	6	5	13	8
Cheese	5	4	7	7
Protein foods				
Eggs	8	5	14	12
Legumes	8	6	14	13
Soy foods[b]	5	1	13	3
Nuts and seeds	7	1	13	8
Beef, lamb, goat, game	8	5	14	10
Pork[b]	5	2	9	5
Poultry	8	5	14	9
Liver	5	0	10	1
Small fish	4	1	10	5
Larger fish	8	3	14	13
Added fats and oils				
Solid fats and saturated oils	7	5	13	11
Other vegetable oils	8	8	12	12

	6-11.9 mo	n=8 countries	12-23.9 mo	n=14 countries
Food groups and subgroups	**# countries where consumed**	**# countries where consumed by ≥ 5%**	**# countries where consumed**	**# countries where consumed by ≥ 5%**
Excluded subgroups				
Other organ meats	3	0	5	1
Insects	0	0	4	0
Crustaceans, cephalopods, bivalves, snails	3	0	8	2
Unhealthy foods and beverages				
Sweet beverages (non-dairy)	7	3	10	9
Bakers' confections (cakes, cookies, etc.)	8	7	14	14
Sugar confections (candy, chocolate, etc.)	7	3	12	7
Salty/fried/fast food snacks	7	5	11	8

[a]Results are for data sets we analyzed; other sources cannot be used for this purpose due to differences in food subgroup definitions. Countries are counted as consuming if even one child consumed. For percents, values are rounded (e.g., 4.5% rounded to 5).

[b]Note that we lacked representation for East and Southeast Asia in these data sets.

Table A3.2 Starchy staple foods: Food subgroups and operational definitions

Whole grains, including flours, pasta, rice, and other grains
Refined grains, including flours, pasta, rice, and other grains
Whole grain dry unsweetened breakfast cereals, including oats
Refined grain dry unsweetened breakfast cereals
Whole grain savory bakery products (breads and similar)
Refined grain savory bakery products (breads and similar)
White-colored starchy roots, tubers, and plantains

General notes:

There are many definitions of 'whole grain' foods, but most are not easily operationalized without, for example, access to label information. For bakery products and breakfast cereals, when data were available, we used the method of Mozaffarian et al. (2013), which evaluates based on a cut-off for the ratio of carbohydrate to fiber. Whole grain bakery items and breakfast cereals were operationally defined as those with a carbohydrate to fiber ratio of ≤ 10:1.

For grains and flours, whole and refined grain representative food items were selected from among available food composition values, with the 'whole' item being one with a relatively lower carbohydrate to fiber ratio. This is because, for example, all types of rice have ratios higher than 10, but there is a distinction between white (higher) and brown rice (lower) ratios.

Breakfast cereals were included in the food subgroups (whole grain and refined) and in calculation of nutrient profiles if they contained ≤ 15 grams total sugar per 100 grams, which is the cut-off in the WHO Regional Office for Europe nutrient profile model related to marketing to children (WHO Regional Office for Europe 2015).

Specific issues:

- Pseudocereals were grouped with whole grains (for example, amaranth, quinoa);
- Certain other grains were grouped with whole grains, unless specified to be refined: barley, teff, sorghum and millet, and their flours;
- When whole or refined form was not specified and we lacked data on fiber content:
  - Wheat flour was grouped with refined grains
  - Rice and rice flour were grouped with refined grains
  - Infant cereals were grouped with refined grain breakfast cereals
  - Bread and wheat bread were grouped with refined grain bakery products
- Maize is challenging and context-specific. When maize meal and/or flour was not specified to be whole grain or refined, and we lacked data on fiber content, we added both whole and refined items to country lists. The exception to this was in Mexico and Guatemala, where we assumed maize flours and their products (masa, tortillas, etc.) were whole grain.
- For sweet potato, if color was unspecified and vitamin A data were unavailable, in Southern Africa we assumed it to be white-fleshed; elsewhere we added both white-fleshed and yellow-orange-fleshed to country lists.
- Pulp from sago and false banana/enset were grouped with starchy roots/tubers/plantains.
- Breadfruit was grouped with starchy roots/tubers/plantains.

Table A3.3 Fruits: Food subgroups and operational definitions

Vitamin A-rich (for example, apricot, cantaloupe, mango, papaya, passion fruit)
Berries
Citrus
Other vitamin C-rich fruits (for example, guava, kiwi, longan, litchi)
Bananas
Avocado and coconut (flesh) and any other high-fat fruits
Other fruit (for example, apples, peaches, pears, pineapple, others)

Notes:

Vitamin A-rich fruits were defined as in the WHO/UNICEF Infant and Young Child Feeding Indicators manual (WHO 2021).

For vitamin C-rich fruits, we selected a cut-off of ≥ 50 mg total ascorbic acid/100 grams of the item, in the form as consumed. This was based on the distribution of vitamin C values for fruits in our global list, and on examination of the most vitamin C-rich fruits in the list of USDA representative foods for food pattern modeling for under-twos (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020).

Specific issues:

- Persimmons were all considered to be the globally-traded Japanese or Asian variety, and grouped with vitamin A-rich fruits
- Gooseberries were grouped with berries
- Dried coconut was excluded, similarly to other dried fruit
- Unspecified 'melon' was grouped with 'other fruit', unless information on vitamin content was available and it was found to be vitamin A-rich

Table A3.4 Vegetables: Food subgroups and operational definitions

Medium to dark green leafy vegetables

Other *Brassicas* (for example, broccoli, cauliflower, cabbage, brussels sprouts, kolhrabi), but not roots/tubers)

Vitamin A-rich orange vegetables (for example,carrots, squash, pumpkin, and orange-fleshed sweet potato)

Peppers and tomatoes

Immature peas and beans (seeds and pods)

Other vegetables (for example, cucumbers, onions, corn, mushrooms, turnip, iceberg lettuce, other)

Notes:

Vegetables of the genus *Brassica* were grouped based on the part of the plant consumed and on color (for example, white vs. green leaves), as these distinctions generally align with differences in nutrient values.

Vitamin A-rich orange vegetables were defined as in the WHO/UNICEF Infant and Young Child Feeding Indicators manual (WHO 2021), with the exception of sweet red peppers. We grouped sweet red peppers in the 'Peppers and tomatoes' group, which also includes tomatillos and similar.

When 'lettuce' was not further defined and vitamin A content not available, we grouped based on knowledge of cuisines, and in cases of uncertainty matched to iceberg lettuce and grouped with other vegetables, to be conservative.

Specific issues:

- Bean sprouts were grouped with other vegetables, rather than with legumes, as water and protein content align with this group
- Root vegetables that are not staples were grouped with other vegetables, for example, parsnip, rutabaga, turnip, and salsify – these tend to be higher in water content than most staple roots and tubers, but there is overlap. The grouping was based on the role in the diet, as this may influence quantities consumed.
- Onions, shallots, and leek are grouped with 'other vegetables', and not considered as condiments.
- We classified unspecified 'peas' or 'beans' based on water and macronutrient content, when available. That is, if water and macronutrient content was similar to dried legumes, we classified with dried legumes, and if similar to fresh peas and beans in the pod, we grouped with these. In cases where we lacked data on water, we were able to specify based on either food groupings in the source document or based on knowledge of context.

Table A3.5 Dairy: Food subgroups and operational definitions

Milk

Yogurt (also including other fermented dairy such as kefir or buttermilk)

Cheese

Notes:

We grouped all forms of yogurt and fermented milks together, based on preliminary analysis of percent water and quantities consumed in several data sets. We compared 'eating yogurts' to 'drinking yogurts/yogurt drinks' and found no clear distinction in water content between the two; rather there was a continuum and some overlap. We also found no difference in average quantities consumed.

As noted above under exclusions, we included most sweetened yogurts but excluded some products marketed as yogurt drinks when they were known to be very low in protein, high in water, and very high in sugar. The included sweetened yogurt products contributed to quantity estimates, but were matched with unsweetened yogurts for purposes of calculating nutrient profiles.

Table A3.6 Protein: Food subgroups and operational definitions

Eggs
Legumes/pulses, and flours made from these
Soy foods
Peanuts/groundnuts, tree nuts, seeds, and pastes made from any of these
Beef, lamb, mutton, goat, and large and small game meat
Pork
Poultry and wild birds
Liver
Fish, small, eaten with bones
Fish, larger, not eaten with bones

Notes:

Initially, we created a group for all organ meats, defined as in the WHO/UNICEF Infant and Young Child Feeding Indicators manual (WHO 2021). However, nutrient profiles for liver differed greatly from those for other organ meats, and other organ meats were even more rarely consumed than was liver, so we chose to narrow an initial 'organ meat' subgroup group to 'liver' from various mammals.

Similarly, initially we had a broader group for fish and seafood (bivalves, crustaceans, cephalopods, and also including both marine and freshwater snails), following the example of the US Food Pattern modeling exercise. However, when developing nutrient profiles, we found high outliers and generally higher values among seafood for several nutrients. Seafood was very rarely consumed, but still had an undue influence on nutrient profiles. Therefore, we excluded seafood from the modeling.

Small fish eaten with bones (vs. larger fish) were classified based on assessment of all available information, including (among others) item descriptions, first-hand knowledge of the research team from previous in-country work, and/or on the food composition database developed for previous Optifood studies, which groups fish based on this characteristic. Most dietary data and food composition data do not distinguish this. We explored using a cut-off based on calcium content per 100 g dry matter, but there was no clear cut-off and there was overlap between values for known examples in the two subgroups. In uncertain cases, fish were classified as larger fish not eaten with bones.

Annex 4 Data sources for modeling inputs

This Annex describes a variety of data sources used in developing Optifood modeling inputs. Data sources were used for any or all of:

- Development of the food item list
- Development of maximum quantities for food subgroups
- Specification of allowed frequency of consumption (days per week) for food groups and subgroups

Search process - data

At the outset of the project, we had access to two nationally representative data sets, from the US and the UK. In the case of the US data, we used a previously processed data set, wherein mixed dishes had been disaggregated into their component ingredients.[24]

We then reviewed data available at two global archives, the WHO/FAO Global Individual Food Consumption data Tool (GIFT), at: https://www.fao.org/gift-individual-food-consumption/en/, and the Global Dietary Database (GDD), at: https://www.globaldietarydatabase.org/, and obtained all other data sets that met the following criteria:

1. Criteria for data sets for food/ingredient lists:
    - Year 2000 or later
    - Included ages 6-23.9 months
    - Information available on nature of study and sampling
    - At least 50 children
2. Additional criterion for data sets for quantities and frequencies of consumption
    - At least 100 per age subgroup (6-11.9 and/or 12-23.9 months)

Advantages of obtaining data from these sources included clear documentation and consistent data formatting, which facilitated analysis. Searches of these two major data archives yielded thirteen data sets.

As we were aware of relevant studies from the International Food Policy Research Institute, we also searched the IFPRI Dataverse housed within the Harvard Dataverse Repository, at: https://dataverse.harvard.edu/dataverse/IFPRI, which yielded two additional data sets. Through literature searches (see below) and personal networks, we identified additional relevant studies, and through this outreach obtained seven additional data sets.

Table A4.1 lists the twenty-four data sets from eighteen countries and provides selected metadata; full citations for data are provided at the end of this Annex. Except as noted, all studies were cross-sectional and were representative for the indicated geographic area. The Table also indicates for which uses each data set was employed. Following Table A4.1, we describe other sources of information and their uses.

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[24] This data processing work was performed during preparation of: Arimond M and Arsenault J. *Scoping exercise for determining feasibility of using nationally-representative quantitative dietary intake data for generating WHO Infant and Young Child Feeding Indicators, within the Global Nutrition Monitoring Framework (GNMF)*. Unpublished consultants' report submitted to the WHO 16 December 2016. Dr. Joanne Arsenault performed the analysis of the US national data and gave permission for use of the processed data set in the current project.

Table A4.1 Data sets

Country	Year(s) of data collection	Geographic scope/area	Nature of sample	Sample size by age group[a]	Uses[b]
AFRICA					
DRC	2014	Sub-national; 9 rural health zones in South Kivu Province, in proximity (60 km) to the capital Bukavu, and Lukaya District in Kongo Central Province	Representative	6-11 mo, n=87 12-23 mo, n=193	FL – all ages PERC, QTY – 12-23 mo
Ethiopia	2013	Sub-national (local); 3 purposively selected rural communities: Guba-Sherero and Holagoba-Kukie in Halaba District, and Edo-Qontola in Zeway District	Representative	6-11 mo, n=40 12-23 mo, n=74	FL only
Kenya[c]	2012	Sub-national; Bondo Sub-county in Siaya County and Teso South Sub-county in Busia County, Western Kenya	Representative; cohort[d]	6-11 mo, n=123 12-23 mo, n=240	FL, PERC, QTY
Kenya[c]	2012	Sub-national; Luanda, Emuhaya, East Tiriki, and West Tiriki Districts in Vihiga County, Western Kenya	Representative	6-11 mo, n=78 12-23 mo, n=118	FL, PERC, QTY
Kenya[c]	2012	Sub-national; Kitui Central, Lower Yatta, Mutomo, and Kitui West Districts in Kitui County, Eastern Kenya	Representative	6-11 mo, n=81 12-23 mo, n=117	FL, PERC, QTY
Kenya[c]	2013	Sub-national; purposively selected communities from 3 livelihood groups: settled communities from Isiolo County, Northeastern Kenya, pastoralist communities from Marsabit County, Northern Kenya, and agro-pastoralist communities from Turkana County, Northwestern Kenya	Representative	6-11 mo, n=537 12-23 mo, n=345	FL, PERC, QTY
Kenya[c]	2016	Sub-national; Loima Sub-county in Turkana County, Northwestern Kenya	Representative	6-11 mo, n=60 12-23 mo, n=140	FL only

Country	Year(s) of data collection	Geographic scope/area	Nature of sample	Sample size by age group[a]	Uses[b]
Kenya[c]	2018	Sub-national; Vihiga County, Western Kenya	Representative	6-11 mo, n=127 12-23 mo, n=217	FL only
Malawi	2010-2011	Sub-national; catchment areas for one hospital and one clinic in Mangochi District	Representative; cohort	At ~9 mo, n=566	FL only
Malawi	2018-2019	Sub-national, rural; catchment areas for one hospital and one clinic in Mangochi District	Representative; cohort[d]	6-11 mo, n=654 12-16 mo, n=298	FL, PERC, QTY
Nigeria	2011	Sub-national; Akwa Ibom State	Representative	6-11 mo, n=67 12-23 mo, n=161	FL – all ages PERC, QTY – 12-23 mo
Zambia	2009	Sub-national; Mkushi District in Central Province and Nyimba District in Eastern Province	Representative; cohort[d]	6-11 mo, n=45 12-23 mo, n=104	FL – all ages PERC, QTY – 12-23 mo

Country	Year(s) of data collection	Geographic scope/area	Nature of sample	Sample size by age group[a]	Uses[b]
AMERICAS					
Ecuador	2012	National	Representative	6-11 mo, n=0 12-23 mo, n=471	FL – 12-23 mo PERC, QTY – 12-23 mo
Mexico	2012	National	Representative	6-11 mo, n=222 12-23 mo, n=518	FL, PERC, QTY
Peru	2015	Sub-national; highlands (4 population centers in Huancavelica Region)	See below[e]	6-11 mo, n=79 12-23 mo, n=118	FL – all ages PERC, QTY – 12-23 mo
United States	2011-2012	National	Representative	6-11 mo, n=170 12-23 mo, n=206	FL, PERC, QTY
ASIA					
Bangladesh	2011-2012	National, rural only	Representative	6-11 mo, n=190 12-23 mo, n=443	FL, PERC, QTY
India	2009-2012	National, rural only	Representative	6-11 mo, n=25 12-23 mo, n=827	FL – all ages PERC, QTY – 12-23 mo
Israel	2009-2012	National	Representative; cohort	12-15 mo, n=887	PERC only – 12-23 mo[f]
Korea	2017	National	Representative	6-11 mo, n=3 12-23 mo, n=66	FL only

Country	Year(s) of data collection	Geographic scope/area	Nature of sample	Sample size by age group[a]	Uses[b]
EUROPE					
Bulgaria	2007	National	Representative	6-11 mo, n=432 12-23 mo, n=282	FL, PERC, QTY
Germany	2008	Subnational, urban (local); city of Dortmund and surrounding communities	Cohort - women recruited via personal contacts, maternity wards, and pediatric practices (convenience sample)	6-11 mo, n=0 12-23 mo, n=173	FL – 12-23 mo PERC, QTY – 12-23 mo
Portugal	2015-2016	National	Representative	6-11 mo, n=209 12-23 mo, n=409	FL, PERC, QTY
United Kingdom	2011	National	Representative	6-11 mo, n=1292 12-17 mo, n=1275	FL, PERC, QTY

[a] Multiple recall days were available for some studies either for all or some infants and young children (IYC); sample sizes listed here are for the first recall day. Surveys with multiple recall days were from Bulgaria, Germany, Kenya (2016, Turkana County; 2018, Vihiga County), Mexico, Portugal, the UK, and the US.

[b] Data from each source could be used for any or all of: the food item list (FL); analyses of the percent of IYC consuming food items and food subgroups (PERC) and of quantities consumed at food subgroup level (QTY). For some data sets, the entire data set contributed to the FL but only one age subgroup had sufficient sample size for analyses of PERC and QTY.

[c] The first four data sets from Kenya were combined for analyses of PERC and QTY. All six Kenya data sets were processed separately for FL. Note also that the geographic descriptions reflect political/administrative divisions at the time of the surveys, some of which have subsequently changed.

[d] Data were collected in 2 rounds. For children with data from both rounds in the same age group, data from one round were randomly selected to preserve independence.

[e] Communities were purposively selected for an intervention. Within communities all eligible and consented households participated in a baseline survey covering two seasons.

[f] Study employed a food frequency questionnaire at the food group level, which in some cases aligned with our food subgroups; could be used for comparing maxima for percent consuming at food subgroup level but did not contribute items to the food item list.

Search process – other sources

To improve geographic representability, we aimed to augment the information gleaned from the data sets listed above. Through literature searches and outreach to colleagues, we identified the following additional sources:

Unpublished data on prevalence of consumption of food items from:

- Helen Keller International's Assessment & Research on Child Feeding (ARCH) project team; information on grams consumed per day was also provided for food items for one country (Nepal)
- The Brazilian National Survey on Child Nutrition (ENANI-2019) study team

Food items lists, with or without prevalence of consumption or gram intakes, from:

- Reports and articles from previous Optifood studies that aimed to develop food-based recommendations for infant and young child feeding
- Studies employing the Process for Promotion of Child Feeding (ProPAN) tool developed by the Pan American Health Organization and partners
- Formative studies undertaken for the Enhancing Nutrition Services to Improve Maternal and Child Health (ENRICH) initiative of Nutrition International and partners
- Published journal articles (and their supplementary materials) obtained from a limited literature search, and limited snowballing (details follow)

The literature search was non-comprehensive, as a more comprehensive search was infeasible given our resources. We searched the PubMed database on 26 August 2021 and updated the search on 23 September 2021, filtering for age under two years and publication date of the year 2000 or later, with the search terms:

> (infant OR 'young child*') AND (diet* OR 'food intake' OR 'complementary food') AND ('24-hour' OR 'food record' OR 'direct observation' OR 'weighed record')

The search returned 414 records and we reviewed all abstracts. Studies were excluded if they covered special populations (hospital patients), and/or if they were from countries for which nationally representative data for infants/young children were publicly available.[25] While studies of hospital patients were excluded, studies with hospital- or out-patient clinic-based samples were included, for example, studies recruiting pregnant women or young children.

Abstracts were further screened for relevance. Articles were potentially relevant if the abstract suggested results included description of foods consumed, and not nutrients only. Potentially relevant articles and supplemental materials were obtained. Further studies were excluded if the sample size in our age range of 6-23.9 months was less than 50 (for example, certain validation studies). Articles that yielded usable food lists and/or data on percent consuming are included in **Table A4.2** and in the citations at the end of this Annex.

Taken together, these additional sources provided information from thirty-two surveys or studies in twenty-six countries, as well as from a multi-country study from Europe. Table A4.2 lists these sources and provides selected metadata. The Table also indicates which sources were used only for food item listings, and which also contributed information on prevalence of consumption or gram intakes.

To improve geographic representability, in two instances we relaxed criteria to include data collected in 1998 and 1999 but published after the year 2000 (hence retrieved from our search:

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[25] Exceptions were small studies from Bangladesh and Mexico, results for which were included in multi-country reports from qualitative studies. Food item lists from these studies were included even though we also had national (Mexico) and national/rural (Bangladesh) data sets.

studies in the Czech Republic and New Zealand). In one instance, for the same reason, we used a food item list from a study covering 6-35 months of age (China).

We also included several studies where prevalence of consumption of each item was not reported, and thus we could not evaluate if each item was consumed by at least 5% of children. However, in these studies, foods were reported at a relatively high level of aggregation and the total food item list was short in comparison to lists coming from data sets. We judged that items on these short lists could be considered to be reasonably commonly consumed, and their inclusion again improved geographic representability (studies from China, France, and Singapore, and the multi-country study from Europe with sites in Belgium, Germany, Italy, Poland and Spain).

Table A4.2 Other data sources

Country	Year of data collection	Geographic scope/area	Nature of sample	Age groups[a]	Uses[b]
AFRICA					
Ethiopia	2011	Sub-national but covering most populous regions: Tigray, Amhara, Oromia & SNNP Regions	Representative for the selected Regions	6-8 mo, n=497 9-11 mo, n=464 12-23 mo, n=1537	FL, QTY
Ghana	2014	Sub-national; Karaga District (Northern Region), Gomoa East District (Central Region)	Representative for the selected Districts	6-8 mo, n=190 9-11 mo, n=195 12-23 mo, n=321	FL, PERC, QTY
Kenya	2017-2018	Sub-national; Elgeyo Marakwet County (western Kenya); purposively selected villages in each of three ecological zones (highlands, escarpment, and Kerio Valley).	Formative study	6-23 mo	FL only
Senegal	2013-2015	Urban/peri-urban areas: Dakar	Clinic-based; health facilities were sampled PPS based on utilization rates	6-11 mo, n=72 12-23 mo, n=146	PERC only[c]
South Africa	Unknown; publication date is 2007	Sub-national; rural Kwazulu Natal, Valley of a Thousand Hills	Recruited all 6-12-mo-old infants in catchment areas of 8 community health centers	6-12 mo; n=475	FL, PERC, QTY
Tanzania	2013-2015	Urban/peri-urban areas: Dar es Salaam	Clinic-based; health facilities were sampled PPS based on utilization rates	6-11 mo, n=79 12-23 mo, n=150	PERC only[c]
Tanzania	2017-2018	Sub-national, Shinyanga and Singida Regions, inland regions in north/central Tanzania ; purposively selected districts within the regions	Formative study	6-23 mo	FL only
AMERICAS					

Country	Year of data collection	Geographic scope/area	Nature of sample	Age groups[a]	Uses[b]
Brazil	2019	National	Representative	6-11 mo, n=1414 12-23 mo, n=2938	FL, PERC
Brazil	2002-2003	Sub-national, peri-urban (Pelotas, Pinheiro machado)	Not described in report; standard PROPAN methodology is random or systematic sampling	6-23 mo; n=~150	FL only
Colombia	2010-2011	Sub-national; Bogota	Recruitment from a hospital-based growth monitoring program	At~12 mo; n=72	FL only
Guatemala	2015-2016	Sub-national, 5 areas prioritized based on stunting	Representative of prioritized areas	6-8 mo, n=453 9-11 mo, n=280 12-23 mo, n=1127	FL, PERC, QTY
Jamaica	2002-2003	Sub-national, peri-urban (Kingston, St. Catherine)	Not described in report; standard PROPAN methodology is random or systematic sampling	6-23 mo; n=~150	FL only
Mexico	2002-2003	Sub-national, peri-urban (Mexico City, Jojutla)		6-23 mo; n=~150	FL only
Panama	2002-2003	Sub-national, peri-urban (Chilibre, Chepo)		6-23 mo; n=~150	FL only
ASIA					
Bangladesh	2017-2018	Sub-national, Thakurgaon, northwest Bangladesh, purposively selected villages	Formative study	6-23 mo	FL only
Cambodia	2013-2015	Urban/peri-urban areas: Phnom Penh	Clinic-based; health facilities were sampled PPS based on utilization rates	6-11 mo, n=73 12-23 mo, n=149	PERC only[c]
China	2015	Tier 1 and Tier 2 cities in China	Cross-sectional; random recruitment based on registries at maternal and child centers	6-35 mo; n=1409, of whom 920 (65%) were aged 6-23 mo	FL only

Country	Year of data collection	Geographic scope/area	Nature of sample	Age groups[a]	Uses[b]
China	2011	Sub-national: Wuyi County, Hebei province, northern China (surrounding, but not including, Beijing and Tianjin)	Representative + formative (mixed methods)	6-23 mo; n=110	FL PERC – 12-23 mo
Indonesia	2010	National	Representative	6-8 mo, n=2768 9-11 mo n=3394 12-23 mo n=2641	FL, QTY
Indonesia	2017	Sub-national; Bandung City	Representative sample of mothers living and seeking child health services in Bandung City	6-11 mo, n=99 12-23 mo, n=213	FL, PERC
Lao PDR	2012	Sub-national, Saravane District (identified as among the poorest in Lao PDR)	15 purposively selected villages; within villages all eligible HH identified and visiting until target sample size achieved	6-23 mo, n=213	FL, QTY
Nepal	2013-2015	Urban/peri-urban areas: Kathmandu Valley	Clinic-based; health facilities were sampled PPS based on utilization rates	6-11 mo, n=78 12-23 mo, n=150	PERC only[c]
Nepal	2017	Sub-national; Kathmandu Valley	Representative, 2-stage cluster sample	6-23 mo; n=745	FL PERC, QTY – 12-23 mo
Pakistan	2017-2018	Sub-national, Sukkur District; purposively selected subunits within the district	Formative study	6-23 mo	FL only

Country	Year of data collection	Geographic scope/area	Nature of sample	Age groups[a]	Uses[b]
Pakistan	2017-2018	National; purposive selection of 12 districts, including 2 from each of the 4 provinces, 1 from each of 3 administrative area (e.g. Islamabad Capital Territory), and 1 from the (former) Federally Administered Tribal Areas (now merged with Khyber Province)	Somewhat representative; within selected districts, livelihood zones had been identified; within these zones, clusters were selected 'based on geographic distribution'; within clusters, systematic random sampling	6-8 mo, n=918 9-11 mo, n=918 12-23 mo, n=918	FL, PERC, QTY
Singapore	2010-2011	Sub-national	Hospital-based; multi-ethnic cohort recruited from two hospitals	6 mo, n=760 9 mo, n=893 12 mo n=907	FL only
Thailand	2003-2005	National	Representative	6-8 mo, n=60 9-11 mo, n=51 12-23 mo, n=202	FL, QTY
Vietnam	2009	National	Representative	6-8 mo, 9-11 mo, 12-23 mo; sample size not available in report	FL, QTY
EUROPE					
Europe multi-country	2002-2010	Study centers in each of: Germany, Belgium, Italy, Poland, and Spain	Hospital-based recruitment; cohort	At ~12 mo; n=633	FL only
Czech Republic	1999-2000	Sub-national; Prague	Hospital-based cohort, random recruitment from maternity	9 mo, n=97 12 mo, n=87 24 mo, n=88	FL – all ages PERC – 6-11 mo (used %s for 9 mo)
France	2005-2009 (recruitment)	Sub-national; Dijon and surrounding cities	Cohort - women recruited from clinics and day care centers (convenience sample)	0-12 mo; n=268	FL only

Country	Year of data collection	Geographic scope/area	Nature of sample	Age groups[a]	Uses[b]
OCEANIA					
Australia	2009-2010	Sub-national; Brisbane and South Australia	Two hospital-based cohorts	14 mo, n=409 24 mo, n=363	FL QTY – 12-23 mo
New Zealand	1998-1999	Sub-national; 3 cities on the So. Island: Christchurch, Dunedin, and Invercargill	Representative of the 3 selected cities; multi-stage random sampling	12-23 mo; n=188	FL PERC, QTY – 12-23 mo

[a] Unlike the surveys in Table A4.1., we could not organize results in consistent age grouping since we did not have data. Age groups shown are age groups as used in the sources (reports and articles); in the case of formative studies employing only qualitative methods, the target age range is indicated without a sample size.

[b] Data from each source could be used for any or all of: the food item list (FL); analyses of the percent of infants and young children consuming food items and food subgroups (PERC) and of quantities consumed at food subgroup level (QTY). For some sources, there was no information on prevalence of consumption or grams consumed, and these sources contributed only to the FL. When there was information on prevalence of consumption and/or grams consumed, we could use this in limited ways, due to differences in subgroupings. Specifically, we could identify instances when prevalence of consumption or grams consumed of a single food item or a subgroup (when aligned) exceeded the maximum for the subgroup found in the data sets listed in Table A4.1. In these instances, data from sources in this table contributed to development of parameters for consumption of food subgroups (see Annex 7 for details).

[c] Study employed a qualitative one-day recall at the food group level. Food groups in some cases aligned with our subgroups and could be used for comparing maxima for percent consuming. Because of the generally broad level of grouping, this data set did not contribute items to the food item list.

The following citations include both data sets and other sources organized by region, and alphabetically by country within regions.

AFRICA

1. Democratic Republic of the Congo – data set
Department of Food, Nutrition and Health, The University of British Columbia; HarvestPlus, International Food Policy Research Institute (IFPRI), 2020, 'Democratic Republic of the Congo (DRC) Micronutrient Cross-Sectional Household Survey', https://doi.org/10.7910/DVN/RNWYR8, Harvard Dataverse, V1, UNF:6:Y2gNPXaq07ScfGC25+LAwQ== [fileUNF]

Associated publication:

Harvey-Leeson, S.; Karakochuk, C.D.; Hawes, M.; Tugirimana, P.L.; Bahizire, E.; Akilimali, P.Z.; Michaux, K.D.; Lynd, L.D.; Whitfield, K.C.; Moursi, M.; Boy, E.; Foley, J.; McLean, J.; Houghton, L.A.; Gibson, R.S.; Green, T.J. Anemia and Micronutrient Status of Women of Childbearing Age and Children 6–59 Months in the Democratic Republic of the Congo. Nutrients 2016, 8, 98. https://doi.org/10.3390/nu8020098

2. Ethiopia – data set
Data set provided to the WHO/FAO GIFT by Getahun Ersino Lombamo, University of Saskatchewan. Dietary Practices, Maternal Nutritional Status and Child Stunting: Comparative and Intervention Studies in Pulse and Non-pulse Growing Rural Communities in Ethiopia, 2013. The harmonization of the dataset was performed by the data owner, and the overall process was overseen by the Global Dietary Database https://www.globaldietarydatabase.org/. Available at the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

Associated publication:

Ersino G, Henry CJ, Zello GA. Suboptimal Feeding Practices and High Levels of Undernutrition Among Infants and Young Children in the Rural Communities of Halaba and Zeway, Ethiopia. Food Nutr Bull. 2016 Sep;37(3):409-424. doi: 10.1177/0379572116658371. https://pubmed.ncbi.nlm.nih.gov/27402640/

3. Ethiopia – Optifood study publication
Samuel A, Osendarp SJM, Ferguson E, Borgonjen K, Alvarado BM, Neufeld LM, Adish A, Kebede A, Brouwer ID. Identifying Dietary Strategies to Improve Nutrient Adequacy among Ethiopian Infants and Young Children Using Linear Modelling. Nutrients. 2019 Jun 24;11(6):1416. doi: 10.3390/nu11061416. PMID: 31238506; PMCID: PMC6627485. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6627485/

4. Ghana – Optifood study report and publication
Brouwer ID, de Jager I, Borgonjen K, Azupogo F, Rooij M, Folson G, Abizari R. 2017. *Development of food-based dietary recommendations for children, 6-23 months old, in Karaga District and Gomoa East District, Ghana.* GAIN: Washington, DC. https://www.gainhealth.org/sites/default/files/publications/documents/gain-usaid-development-of-food-based-recommendations-using-optifood-ghana-2017.pdf

Associated publication:

de Jager I, Borgonjen-van den Berg KJ, Giller KE, Brouwer ID. Current and potential role of grain legumes on protein and micronutrient adequacy of the diet of rural Ghanaian infants and young children: using linear programming. Nutr J. 2019 Feb 21;18(1):12. doi: 10.1186/s12937-019-0435-5. PMID: 30791898; PMCID: PMC6385461. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6385461/

5. Kenya (Bondo and Teso South) – data set
Data set provided to the WHO/FAO GIFT by Bioversity International. Improving nutrition through increased utilisation of local agricultural biodiversity in Kenya – the INULA initiative. Baseline data 2012. Available at the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

Associated publication:

Waswa LM, Jordan I, Herrmann J, Krawinkel MB, Keding GB. Community-based educational intervention improved the diversity of complementary diets in western Kenya: results from a randomized controlled trial. Public Health Nutr. 2015 Dec;18(18):3406-19. doi: 10.1017/S1368980015000920. https://pubmed.ncbi.nlm.nih.gov/25857703/

6. Kenya (Isiola, Marsabit, and Turkana) – data set
Infant and young child dietary data from three food-insecure counties in northern Kenya. Data collected for an Optifood study; funding for this work was provided by the Global Alliance for Improved Nutrition (GAIN). Data are available at: https://www.gainhealth.org/resources/datasets

Associated publication:

Vossenaar M, Knight FA, Tumilowicz A, Hotz C, Chege P, Ferguson EL. Context- specific complementary feeding recommendations developed using Optifood could improve the diets of breast-fed infants and young children from diverse livelihood groups in northern Kenya. Public Health Nutr. 2017 Apr;20(6):971-983. doi: 10.1017/S1368980016003116. Epub 2016 Dec 5. PMID: 27917743. https://pubmed.ncbi.nlm.nih.gov/27917743/

7. Kenya (Kitui) – data set
Infant and young child dietary data from two rural agro-ecological zones in south-central Kenya. Data collected for an Optifood study; funding for this work was provided by the Global Alliance for Improved Nutrition (GAIN). Data are available at: : https://www.gainhealth.org/resources/datasets

Associated publication:

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

8. Kenya (Turkana) – data set
Data set provided to the WHO/FAO GIFT by Bioversity International. Innovative, participatory tools for dietary assessment and nutrition education in Turkana County – Diagnostic survey 2016. Available at the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

Associated publication:

Sarfo J, Keding GB, Boedecker J, Pawelzik E, Termote C. The Impact of Local Agrobiodiversity and Food Interventions on Cost, Nutritional Adequacy, and Affordability of Women and Children's Diet in Northern Kenya: A Modeling Exercise. Front Nutr. 2020 Aug 13;7:129. doi: 10.3389/fnut.2020.00129. https://pubmed.ncbi.nlm.nih.gov/32903921/

9. Kenya (Vihiga) – data set
Infant and young child dietary data from two rural agro-ecological zones in south-central Kenya. Data collected for an Optifood study; funding for this work was provided by the Global Alliance for Improved Nutrition (GAIN). Data are available at: https://www.gainhealth.org/resources/datasets

Associated publication:

Ferguson E et al., 2015, *op. cit.*

10. Kenya (Vihiga) – data set
Data set provided to the WHO/FAO GIFT by Bioversity International. Improving access to and benefits from a wealth of diverse seeds to support on-farm biodiversity for healthy people in resilient landscapes: Baseline Survey 2018. Available at the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

Associated publication:

Boedecker J, Odhiambo Odour F, Lachat C, Van Damme P, Kennedy G, Termote C. Participatory farm diversification and nutrition education increase dietary diversity in Western Kenya. Matern Child Nutr. 2019 Jul;15(3):e12803. doi: 10.1111/mcn.12803. https://pubmed.ncbi.nlm.nih.gov/30827036/

11. Kenya – ENRICH Project report and publication
Nutrition International. 2019. ENRICH Kenya Formative Research: Final Report. Nutrition International: Ottawa. https://www.nutritionintl.org/location/kenya/page/4/

Associated publication:

Robert RC, Bartolini RM, Creed-Kanashiro HM, Verney Sward A. Using formative research to design context-specific animal source food and multiple micronutrient powder interventions to improve the consumption of micronutrients by infants and young children in Tanzania, Kenya, Bangladesh and Pakistan. Matern Child Nutr. 2021 Apr;17(2):e13084. doi: 10.1111/mcn.13084. Epub 2020 Oct 16. PMID: 33064374; PMCID: PMC7988862. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7988862/

12. Malawi – data set
Data are from the Malawi iLiNS-DOSE trial. Data were provided by Jaimie Hemsworth, Elaine Ferguson, and Tampere University. We used a food/ingredient-level file that is not publicly available. Nutrient intake data for this study are available on request from Tampere University.

Associated publication:

Hemsworth J, Kumwenda C, Arimond M, Maleta K, Phuka J, Rehman AM, Vosti SA, Ashorn U, Filteau S, Dewey KG, Ashorn P, Ferguson EL. Lipid-Based Nutrient Supplements Increase Energy and Macronutrient Intakes from Complementary Food among Malawian Infants. J Nutr. 2016 Feb;146(2):326-34. doi: 10.3945/jn.115.215327. Epub 2016 Jan 6. PMID: 26740684. https://academic.oup.com/jn/article/146/2/326/4584826

13. Malawi – data set
Data are from the Malawi Mazira trial. Data sharing was approved by the principal investigators (Lora Iannotti, Chessa Lutter, Kenneth Maleta, and Christine Stewart) and were shared by Bess Caswell and Charles Arnold of the University of California, Davis. We used a food/ingredient-level file that is not publicly available.

Associated publication:

Lutter CK, Caswell BL, Arnold CD, Iannotti LL, Maleta K, Chipatala R, Prado EL, Stewart CP. Impacts of an egg complementary feeding trial on energy intake and dietary diversity in Malawi. Matern Child Nutr. 2021 Jan;17(1):e13055. doi: 10.1111/mcn.13055. Epub 2020 Jul 20. PMID: 33128502; PMCID: PMC7729770. https://pubmed.ncbi.nlm.nih.gov/33128502/

14. Nigeria – data set
International Institute of Tropical Agriculture (IITA); HarvestPlus, International Food Policy Research Institute (IFPRI), 2015, '001_Nigeria-Cassava_FoodList-Long.tab', Dietary intakes, vitamin A, and iron status of women of childbearing age and children 6-59 months of age from Akwa Ibom state in Nigeria, https://doi.org/10.7910/DVN/29604/FIXL75, Harvard Dataverse, V6, UNF:6:YtB+j8/cJM+zh/7+4fMqdg== [fileUNF]

Associated publication:

De Moura FF, Moursi M, Lubowa A, Ha B, Boy E, Oguntona B, Sanusi RA, Maziya-Dixon B. Cassava Intake and Vitamin A Status among Women and Preschool Children in Akwa-Ibom, Nigeria. PLoS One. 2015 Jun 17;10(6):e0129436. doi: 10.1371/journal.pone.0129436. PMID: 26083382; PMCID: PMC4470824. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4470824/

15. Senegal – ARCH Project, phase 1, processed data and publication
Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Pries AM, Huffman SL, Champeny M, Adhikary I, Benjamin M, Coly AN, Diop EHI,Mengkheang K, Sy NY, Dhungel S, Feeley A, Vitta B, Zehner E. Consumption of commercially produced snack foods and sugar-sweetened beverages during the complementary feeding period in four African and Asian urban contexts. Matern Child Nutr. 2017 Oct;13 Suppl 2(Suppl 2):e12412. doi: 10.1111/mcn.12412. PMID: 29032629; PMCID: PMC6865897. https://pubmed.ncbi.nlm.nih.gov/29032629/

16. South Africa - publication
Faber M. Complementary foods consumed by 6-12-month-old rural infants in South Africa are inadequate in micronutrients. Public Health Nutr. 2005 Jun;8(4):373-81. doi: 10.1079/phn2004685. PMID: 15975182. https://www.cambridge.org/core/journals/public-health-nutrition/article/complementary-foods-consumed-by-6-12monthold-rural-infants-in-south-africa-are-inadequate-in-micronutrients/E8E85B734DF80DC3883E34417F6C7E9C#article

17. Tanzania – ARCH Project, phase 1, processed data and publication
Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Pries et al., op. cit.

18. Tanzania – ENRICH Project report and publication
Nutrition International. 2019. ENRICH Tanzania Formative Research: Final Report. Nutrition International: Ottawa. https://www.nutritionintl.org/location/tanzania/

Associated publication:

Robert et al., *op. cit.*

19. Zambia – data set

Data set provided to the WHO/FAO GIFT by the Tropical Diseases Research Centre (TDRC: Ndola, Zambia); National Food and Nutrition Commission (NFNC: Lusaka, Zambia); HarvestPlus, and the International Food Policy Research Institute (IFPRI). The 2009 Food consumption and Vitamin A status survey in Zambia. Available from the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

Associated publications:

Hotz C, Palaniappan U, Chileshe J, Kafwembe E, Siamusantu W. 2011. *Nutrition Survey in Central and Eastern Provinces, Zambia 2009: Focus on Vitamin A and Maize Intakes, and Vitamin A Status among Women and Children*. Lusaka and Washington (DC): National Food and Nutrition Commission of Zambia, Tropical Diseases Research Centre, Zambia, and Harvest Plus.

Hotz C, Chileshe J, Siamusantu W, Palaniappan U, Kafwembe E. Vitamin A intake and infection are associated with plasma retinol among pre-school children in rural Zambia. Public Health Nutr. 2012 Sep;15(9):1688-96. doi: 10.1017/S1368980012000924. https://pubmed.ncbi.nlm.nih.gov/22443986/

AMERICAS

1. Brazil – processed data and publication

Acknowledgement: Gilberto Kac, Inês Rugani, Elisa Lacerda and Letícia Vertulli. Data from the Brazilian National Survey on Child Nutrition (ENANI-2019) were analyzed and provided in tabulated format by the study team. Data are not publicly available.

Associated publication:

Alves-Santos NH, Castro IRR, Anjos LAD, Lacerda EMA, Normando P, Freitas MB, Farias DR, Boccolini CS, Vasconcellos MTL, Silva PLDN, Kac G. General methodological aspects in the Brazilian National Survey on Child Nutrition (ENANI-2019): a population-based household survey. Cad Saude Publica. 2021 Aug 30;37(8):e00300020. doi: 10.1590/0102-311X00300020. PMID: 34495099. https://www.scielo.br/j/csp/a/vVgZh3zyPFVsNzfnKKCBZ6k/?lang=en

2. Brazil, Jamaica, Mexico, Panama – PROPAN four-country study reports

Frongillo EA, Arabi M, Sywulka SM, Campirano-Nuñez AF, Damsgaard CT. 2003. Draft report with results of cross-country analysis for Pan American Health Organization study: Forging a Strategy to Prevent Early Childhood Malnutrition Though Improving Complementary Feeding Practices and Access to Fortified Foods. Cornell University: Ithaca, NY. Unpublished report, personal communication from Helena Pachón.

Pachón H, Arabi M. 2004. Forging a Strategy to Prevent Early Childhood Malnutrition through Improving Complementary Feeding Practices and Access to Fortified Foods (PAHO Multicenter Study): Description of Datasets. Cornell University: Ithaca, NY. Unpublished document, personal communication from Helena Pachón.

Associated information: General PROPAN methodology:

Pan American Health Organization. United Nations Children's Fund. 2013. ProPAN: Process for the Promotion of Child Feeding. 2. ed. PAHO: Washington, D.C. https://www.paho.org/hq/dmdocuments/2013/Propan2-Eng.pdf

3. Colombia – Optifood study publication

Tharrey M, Olaya GA, Fewtrell M, Ferguson E. Adaptation of New Colombian Food-based Complementary Feeding Recommendations Using Linear Programming. J Pediatr Gastroenterol Nutr. 2017 Dec;65(6):667-672. doi: 10.1097/MPG.0000000000001662. PMID: 28644370. https://journals.lww.com/jpgn/Fulltext/2017/12000/Adaptation_of_New_Colombian_Food_based.16.aspx

Associated publication:

Olaya GA, Lawson M, Fewtrell MS. Efficacy and safety of new complementary feeding guidelines with an emphasis on red meat consumption: a randomized trial in Bogota, Colombia. Am J Clin Nutr. 2013 Oct;98(4):983-93. doi: 10.3945/ajcn.112.053595. Epub 2013 Aug 14. PMID: 23945724. https://academic.oup.com/ajcn/article/98/4/983/4577278

4. Ecuador – data set

Encuesta Nacional de Salud y Nutricion (ENSANUT-ECU) 2011-2013. Ministerio de Salud Publica. Instituto Nacional de Estadistica y Censos. Quito, Ecuador. Harmonized for the Global Dietary Database. Accessed at: www.globaldietarydatabase.org/management/microdata-surveys.

5. Guatemala – Optifood study processed data and report

Acknowledgement: Frances Knight provided Optifood inputs (processed files) and details on sampling to augment the results report.

Associated publication:

INCAP, SESAN, CRS, UNICEF. and WFP. 2016. *Brechas Nutricionales En Los Niños Y Niñas De 6 A 23 Meses Y Sus Madres En Guatemala. Informe Final.* Instituto de Nutrición de Centro América y Panamá (INCAP): Guatemala City. http://www.incap.int/index.php/es/publicaciones-conjuntas-con-otras-instituciones/720-brechas-nutricionales-en-los-ninos-y-ninas-de-6-a-23-meses-y-sus-madres-en-guatemala-informe-final-analisis-desagregado-por-sexo-incap-dce-157/file

6. Mexico – data set

Mexican National Health and Nutrition Survey, 2012, National Institute of Public Health, Mexico. Harmonized for the Global Dietary Database. Accessed at: www.globaldietarydatabase.org/management/microdata-surveys.

7. Peru – data set

Unpublished data were provided by the Instituto de Investigación Nutricional (IIN), Lima, Peru, with permission from the NGO Grupo Yanapai. Data are dietary intake of infants and young children 6 - 23 months, whose families participated in the project: 'Sembrando la Dieta Andina: Escalando el uso de la agrobiodiversidad para una mejor nutrición infantil en comunidades de Huancavelica' in Yauli, Huancavelica, Peru. Data are from a baseline survey in 2015, prior to an intervention. This was a project of the Grupo Yanapai and IIN (IIN was responsible for the dietary data: Lizette Ganoza, Hilary Creed-Kanashiro).

8. United States – processed data set

Data and other documentation from multiple rounds of the What We Eat in America – National Health and Nutrition Examination Survey (WWEIA-NHANES) are available at: https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/wweia-documentation-and-data-sets/. However, because we needed to use ingredient level data, we chose to use processed data from the 2011-2012 survey round, provided by Joanne Arsenault and Mary Arimond.

The data processing work was performed during preparation of: Arimond M and Arsenault J. *Scoping exercise for determining feasibility of using nationally-representative quantitative dietary intake data for generating WHO Infant and Young Child Feeding Indicators, within the Global Nutrition Monitoring Framework (GNMF).* Unpublished consultants' report submitted to WHO 16 December 2016. Joanne Arsenault performed the analysis of the US national data and gave permission for use of the processed data set in the current project.

ASIA

1. Bangladesh – data set

Bangladesh Integrated Household Survey (BIHS), 2011-2012; International Food Policy Research Institute. Harmonized for the Global Dietary Database. Accessed at www.globaldietarydatabase.org/management/microdata-surveys.

2. Bangladesh – ENRICH Project report and publication

Nutrition International. 2019. ENRICH Bangladesh Formative Research: Final Report. Nutrition International: Ottawa. https://www.nutritionintl.org/location/bangladesh/page/2/

Associated publication:

Robert et al., *op. cit.*

3. Cambodia – ARCH Project, phase 1, processed data and publication

Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Pries et al., op. cit.

4. China (Wuyi) - publication

Wu Q, van Velthoven MH, Chen L, Car J, Rudan D, Saftić V, Zhang Y, Li Y, Scherpbier RW. Improving the intake of nutritious food in children aged 6-23 months in Wuyi County, China -- a multi-method approach. Croat Med J. 2013 Apr;54(2):157-70. doi: 10.3325/cmj.2013.54.157. PMID: 23630143; PMCID: PMC3662389. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3662389/

5. China (Tier 1 and Tier 2 cities) - publication

Wang, H., Denney, L., Zheng, Y. et al. Food sources of energy and nutrients in the diets of infants and toddlers in urban areas of China, based on one 24-hour dietary recall. BMC Nutr 1, 19 (2015). https://doi.org/10.1186/s40795-015-0014-x

6. India – data set

Data set provided to the WHO/FAO GIFT by ICMR, National Institute of Nutrition, India. Diet and Nutritional Status of Rural Population, Prevalence of Hypertension and Diabetes among Adults, and Infant and Young child feeding practices, 2009-2012, Indian Council of Medical Research, National Institute of Nutrition, Hyderabad. The harmonization of the dataset was performed by the data owner, and the overall process was overseen by the Global Dietary Database https://www.globaldietarydatabase.org/. Available at the WHO/FAO GIFT at: https://www.fao.org/gift-individual-food-consumption/data-and-indicator/en/

7. Indonesia – ARCH Project, phase 2, processed data and publication

Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Green M, Hadihardjono DN, Pries AM, Izwardy D, Zehner E, Huffman SL. High proportions of children under 3 years of age consume commercially produced snack foods and sugar-sweetened beverages in Bandung City, Indonesia. Matern Child Nutr. 2019 Jun;15 Suppl 4(Suppl 4):e12764. doi: 10.1111/mcn.12764. PMID: 31225706; PMCID: PMC6619027. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6619027/

8. Indonesia – Optifood, SMILING Project report and publication

Fahmida U, Santika O, Ferguson E. SMILING PROJECT Country Report for Indonesia. Personal communication from Elaine Ferguson, 30 June 2021.

Associated publication:

Ferguson EL, Watson L, Berger J, Chea M, Chittchang U, Fahmida U, Khov K, Kounnavong S, Le BM, Rojroongwasinkul N, Santika O, Sok S, Sok D, Do TT, Thi LT, Vonglokham M, Wieringa F, Wasantwisut E, Winichagoon P. Realistic Food-Based Approaches Alone May Not Ensure Dietary Adequacy for Women and Young Children in South-East Asia. Matern Child Health J. 2019 Jan;23(Suppl 1):55-66. doi: 10.1007/s10995-018-2638-3. PMID: 30269204. https://pubmed.ncbi.nlm.nih.gov/30269204/

9. Israel – data set

Ministry of Health, Israel. Mabat Infant National Health and Nutrition Survey, Birth to Age 2 years, 2009-2012. https://www.health.gov.il/UnitsOffice/ICDC/mabat/Pages/Mabat_Infant.aspx

Associated publication:

Ministry of Health, Israel. 2014. Mabat Infant National Health and Nutrition Survey, Birth to Age 2 years, 2009-2012. Israel Center for Disease Control (ICDC) Publication No. 352. Tel Hashomer: ICDC. https://www.health.gov.il/PublicationsFiles/mabat-infant.pdf.pdf

10. Korea – data set

The Seventh Korea National Health and Nutrition Examination Survey (KNHANES VII-2), 2017; Korea Centers for Disease Control and Prevention. Harmonized for the Global Dietary Database. Accessed at www.globaldietarydatabase.org/management/microdata-surveys.

11. Lao PDR – Optifood, SMILING Project

Vonglokham M, Kounnavong S, Douangvichith D, Akkhavong K, Watson L, Ferguson E. SMILING PROJECT Country Report for Lao PDR. Personal communication from Elaine Ferguson, 30 June 2021.

Associated publication:

Ferguson et al., 2019, *op. cit.*

12. Nepal – ARCH Project, phase 1, processed data and publication

Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Pries et al., op. cit.

13. Nepal – ARCH Project, phase 2, processed data and publication

Acknowledgement: Alissa Pries, and Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

Associated publication:

Pries AM, Rehman AM, Filteau S, Sharma N, Upadhyay A, Ferguson EL. Unhealthy Snack Food and Beverage Consumption Is Associated with Lower Dietary Adequacy and Length-for-Age z-Scores among 12-23-Month-Olds in Kathmandu Valley, Nepal. J Nutr. 2019 Oct 1;149(10):1843-1851. doi: 10.1093/jn/nxz140. PMID: 31309223; PMCID: PMC6768809. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6768809/

14. Pakistan – ENRICH Project report and publication
Nutrition International. 2019. ENRICH Pakistan Formative Research: Final Report. Nutrition International: Ottawa. https://www.nutritionintl.org/location/pakistan/

Associated publication:

Robert et al., *op. cit.*

15. Pakistan – Optifood study reports
UNICEF Pakistan & Ministry of National Health Services, Regulations and Coordination. 2018. Optifood Analysis Report Pakistan. UNICEF Pakistan & Ministry of National Health Services, Regulations and Coordination: Islamabad. https://www.unicef.org/pakistan/reports/optifood-analysis-report-pakistan

UNICEF Pakistan & Ministry of National Health Services, Regulations and Coordination. 2018. Cost of the Diet Analysis Report in 12 Districts, 17 Livelihood Zones - Pakistan. UNICEF Pakistan & Ministry of National Health Services, Regulations and Coordination: Islamabad. https://www.unicef.org/pakistan/reports/cost-diet-analysis-report-pakistan

16. Singapore - publication
Lim SX, Toh JY, van Lee L, Han WM, Shek LP, Tan KH, Yap F, Godfrey KM, Chong YS, Chong MF. Food Sources of Energy and Macronutrient Intakes among Infants from 6 to 12 Months of Age: The Growing Up in Singapore Towards Healthy Outcomes (GUSTO) Study. Int J Environ Res Public Health. 2018 Mar 10;15(3):488. doi: 10.3390/ijerph15030488. PMID: 29534442; PMCID: PMC5877033. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5877033/

17. Thailand – Optifood, SMILING Project
Chittchang U, Rojroongwasiukul N, Winnichagoon P, Wasantwisut E, Watson L, Ferguson E. SMILING PROJECT Country report for Thailand. Personal communication from Elaine Ferguson, 30 June 2021.

Associated publication:

Ferguson et al., 2019, *op. cit.*

18. Vietnam – Optifood, SMILING Project
Le Bach Mai, Thi Tran Lua, Thanh Do Tran, Hong Dung Le, Huy Tue Ha, Watson Louise, Ferguson Elaine. SMILING PROJECT Country Report for Vietnam. Personal communication from Elaine Ferguson, 30 June 2021.

Associated publication:

Ferguson et al., 2019, *op. cit.*

EUROPE

1. **Belgium, Germany, Italy, Poland, and Spain – EU CHOP multi-country study publication**
Luque V, Escribano J, Closa-Monasterolo R, Zaragoza-Jordana M, Ferré N, Grote V, Koletzko B, Totzauer M, Verduci E, ReDionigi A, Gruszfeld D, Socha P, Rousseaux D, Moretti M, Oddy W, Ambrosini GL. Unhealthy Dietary Patterns Established in Infancy Track to Mid-Childhood: The EU Childhood Obesity Project. J Nutr. 2018 May 1;148(5):752-759. doi: 10.1093/jn/nxy025. PMID: 29982656. https://pubmed.ncbi.nlm.nih.gov/29982656/

2. **Bulgaria – data set**
Data set provided to the WHO/FAO GIFT by National Center of Public Health and Analysis (NCPHA), Bulgaria. Nutrition and Nutritional Status of Children under 5 years in Bulgaria (NUTRICHILD), 2007. The harmonization of the dataset was performed by the data owner, and the overall process was overseen by EFSA [European Food Safety Authority. EFSA Comprehensive European Food Consumption Database. http://www.efsa.europa.eu/en/food-consumption/comprehensive-database and the Global Dietary Database https://www.globaldietarydatabase.org

3. **Czech Republic - publication**
Kudlova E, Rames J. Food consumption and feeding patterns of Czech infants and toddlers living in Prague. Eur J Clin Nutr. 2007 Feb;61(2):239-47. doi: 10.1038/sj.ejcn.1602493. Epub 2006 Aug 16. PMID: 16929247. https://pubmed.ncbi.nlm.nih.gov/16929247/

4. **France – publication**
Yuan WL, Lange C, Schwartz C, Martin C, Chabanet C, de Lauzon-Guillain B, Nicklaus S. Infant Dietary Exposures to Sweetness and Fattiness Increase during the First Year of Life and Are Associated with Feeding Practices. J Nutr. 2016 Nov;146(11):2334-2342. doi: 10.3945/jn.116.234005. Epub 2016 Oct 12. PMID: 27733527. https://academic.oup.com/jn/article/146/11/2334/4630460

5. **Germany – data set**
Dortmund Nutritional and Anthropometric Longitudinally Designed Study (DONALD Study), 2006-2008; University of Bonn, Nutritional Epidemiology, Germany. Harmonized for the European Food Safety Authority and the Global Dietary Database. Accessed at www.globaldietarydatabase.org/management/microdata-surveys.

6. **Portugal – data set**
The Portuguese National Food, Nutrition, and Physical Activity Survey (IAN-AF), 2015-2016; University of Porto. Harmonized for the European Food Safety Authority and the Global Dietary Database. Accessed at www.globaldietarydatabase.org/management/microdata-surveys.

7. **United Kingdom – data set**
Medical Research Council, Epidemiology and Medical Care Unit, NatCen Social Research, University of Newcastle upon Tyne, Institute for Ageing and Health, Human Nutrition Research Centre, Medical Research Council, Resource Centre for Human Nutrition Research, 2013, Diet and Nutrition Survey of Infants and Young Children, 2011, [data collection], UK Data Service, 2nd Edition, Accessed 23 August 2021. SN: 7263, http://doi.org/10.5255/UKDA-SN-7263-2. Data are available after application at https://ukdataservice.ac.uk/.

The survey report and associated documentation are available at: https://www.gov.uk/government/publications/diet-and-nutrition-survey-of-infants-and-young-children-2011

OCEANIA

1. Australia - publications

Mauch C, Magarey A, Byrne R, Daniels L. Serve sizes and frequency of food consumption in Australian children aged 14 and 24 months. Aust N Z J Public Health. 2017 Feb;41(1):38-44. doi: 10.1111/1753-6405.12622. Epub 2016 Dec 13. PMID: 27960228.
https://onlinelibrary.wiley.com/doi/epdf/10.1111/1753-6405.12622

Byrne R, Magarey A, Daniels L. Maternal perception of weight status in first-born Australian toddlers aged 12-16 months--the NOURISH and SAIDI cohorts. Child Care Health Dev. 2016 May;42(3):375-81. doi: 10.1111/cch.12335. Epub 2016 Mar 21. PMID: 27001154.
https://onlinelibrary.wiley.com/doi/10.1111/cch.12335

2. New Zealand - publication

Szymlek-Gay E, Ferguson E, Heath A-L, Fleming E. Quantities of foods consumed by 12- to 24-month-old New Zealand children. Nutr Diet. 2010;67:244-250.
https://onlinelibrary.wiley.com/doi/10.1111/j.1747-0080.2010.01471.x

Annex 5 Development of the food composition database

We selected the USDA National Nutrient Database for Standard Reference, Release 28, as our primary source, followed by the survey-linked USDA Food and Nutrient Database for Dietary Studies (2017-2018 survey round). Full citations for these and other databases are at the end of this Annex.

When there was no good match for a given food item in either of two US databases, we searched other databases in the following general order of preference:

- National food composition databases from the relevant country
- Regional food composition databases (the West African and the Southeast Asian (ASEAN) databases)
- The Optifood internal food composition database
- The FAO global, biodiversity, and fish food composition databases
- Project databases, and up to one other national database from a neighboring country

However, when the food item in question was from a project area, we preferred project databases over other non-US sources. One author (EF) was on the project teams and involved in the development of the project databases selected for use.

Items that are fortified in the US food supply were an exception. For these items (that is, certain dairy and grain/cereal products), we used unfortified items from the German national food composition database (20 items).

The development of the food composition database followed from and was interlinked with the development of the food item list. This Annex provides further details on these interlinked tasks, and documents:

- Number and percent of all food item nutrient values from each source database
- Selected forms of foods per food subgroup, and the use of yield and retention factors
- Item clustering, and matching to food composition data
- Handling of missing values for nutrient data
- Selection of nutrient values for unhealthy foods and beverages and for fortified items
- Citations for all food composition databases

Number and percent of all food item nutrient values from each source database

Table A5.1 Sources for food composition data[a, b, c, d]

Source	# items	Percent
US sources (primary)		
US SR 28	282	74.2
US FNDDS	1	0.3
Global databases		
FAO INFOODS Biodiversity	1	0.3
Regional databases		
ASEAN	8	2.1
West African	14	3.7
National databases		
Australia	2	0.5
Bangladesh	2	0.5
France	5	1.3
Germany	20	5.3
India	1	0.3
Japan	1	0.3
Kenya	2	0.5
Korea	4	1.1
Malawi	3	0.8
Mexico	1	0.3
Nigeria	3	0.8
Peru	3	0.8
Project databases		
Malawi iLiNS DOSE Project	1	0.3
Optifood internal database	10	2.6
Vietnam SMILING Project	5	1.3
Other sources		
Back-calculations[e]	6	1.6
Recipes[f]	3	0.8
Published literature[g]	2	0.5

[a] Citations for all food composition databases are at the end of this Annex

[b] ASEAN = The Association of Southeast Asian Nations; INFOODS = International Network of Food Data Systems; iLiNS DOSE = The International Lipid-Based Nutrient Supplements (iLiNS) Project trial; SMILING = Sustainable Micronutrient Interventions to Control Deficiencies and Improve Nutritional Status and General Health in Asia; US FNDDS = USDA Food and Nutrient Database for Dietary Studies; US SR 28 = USDA National Nutrient Database for Standard Reference, Release 28.

[c] Table A5.1 does not include unhealthy items or fortified items; sources for nutrient data for these are detailed in another section.

[d] For 30 items, nutrient data were obtained from more than one source. One source provided information for most nutrients, but values were imputed from another source for one or several nutrients. This table documents the number and percent of items based on the main source, i.e. the one that provided data for most nutrients.

[e] For food items in the Ethiopian data set that could not be matched to food composition data, we back-calculated food composition data based on intake data.

[f] For several items, we calculated the nutrient composition based on recipes.

[g] For two items, we use values in Nölle et al. (2020). In addition, we imputed values for fatty acids for one item from Jimenez et al. (2015).

Selected forms of foods per food subgroup and use of yield and retention factors

For certain food groups, it was necessary to impose a single form on all food items, so that large differences in water content would not muddle subgroup nutrient profiles or estimation of maximum quantities.

For example, since our data sources were diverse they could list legume items in any of three ways:

- In raw form, when dietary data were at ingredient level and items were dry ingredients in recipes
- In cooked form (usually, boiled)
- Unspecified form – for example when item lists were drawn from tables and reports in publications

Averaging across the first two would be undesirable for nutrient profiles and for determining modeling parameters for maximum quantities. And for the third, a form had to be selected when matching to food composition data. So, for legumes, we harmonized by matching all legumes to the dry form.

See **Table A5.2** for documentation of selected forms for each food subgroup. Each food item in the source lists was matched to nutrient composition data for the indicated form, adjusted for retention if applicable (see below).

Note that we did not aim for exact equivalence in water content, but rather aimed to avoid large differences. So, for example, for vegetables, water content of raw vs. cooked forms varies, but not extremely. Because of this, we allowed either form within certain subgroups.

When we needed to convert between cooked and dried forms to estimate quantities consumed and to develop nutrient profiles, we applied yield factors. Yield factors were computed based on the ratio of dry matter in the cooked form to dry matter in the raw form or vice versa, depending on the direction of the conversion. To compute dry matter content, data on water in the dry and cooked forms were taken from US SR 28. If nutrient data were not available in this primary source, they were sourced from other FCTs.

When developing nutrient profiles, we applied nutrient retention factors to the raw, dry forms (for example, grains and legumes), to ingredients in recipe calculations, and, rarely, to food items consumed in cooked form for which nutrient data were only available for the raw form. All nutrient retention factors were selected from the USDA Nutrient Retention Factors, release 6, available at: https://data.nal.usda.gov/dataset/usda-table-nutrient-retention-factors-release-6-2007.

Table A5.2 Selected forms for food subgroups

Food groups and subgroups	Selected form(s)
Starchy staple foods	
Whole grains, incl. flours, pasta, rice, and other grains	Dry, raw
Refined grains, incl. flours, pasta, rice, and other grains	Dry, raw
Whole grain dry breakfast cereals	Dry, raw
Refined grain dry breakfast cereals	Dry, raw
Whole-grain savory bakery products	As is, baked
Refined-grain savory bakery products	As is, baked
White-colored starchy roots, tubers, and plantains	Boiled and drained
Fruits	
All fruit subgroups	As is from source list, raw or cooked[a]
Vegetables	
Medium to dark green leafy vegetables	Boiled and drained, with exceptions[b]
Other *Brassicas,* not including roots/tubers	Boiled and drained
Vitamin A-rich orange vegetables	Boiled and drained
Peppers and tomatoes	Boiled and drained, unless specified as raw
Immature peas and beans	Boiled and drained
Other vegetables	Boiled and drained, with exceptions[c]
Dairy products	
Milk	Fluid
Yogurt/fermented dairy	As is
Cheese	As is
Protein foods	
Eggs	Boiled
Legumes/pulses, and their flours	Dry
Soy foods	Boiled soy beans and soy flour, raw tofu
Peanuts/groundnuts, tree nuts, and seeds	Dry/paste
Beef, lamb, mutton, goat, game	Cooked[d]
Pork	Cooked[d]
Poultry and wild birds	Cooked[d]
Liver	Cooked[d]
Fish, small, eaten with bones	Cooked[d]
Fish, larger, not eaten with bones	Cooked[d]

[a] For fruits either form was allowed, but almost all were listed in raw form.

[b] Exceptions included medium to dark green lettuces and endives, and other items we judged more likely to be given raw.

[c] Exceptions included cucumbers, iceberg lettuce, and other items we judged more likely to be given raw.

[d] For meat, poultry, and fish we looked for wet-cooked (boiled, braised or simmered) but if these were unavailable also accepted roasted values or (rarely) raw values. Raw values were retention-adjusted.

Item clustering and matching to food composition data

Item clustering in data sources

Item clustering is the grouping of similar items, and it appeared to a greater or lesser degree in many of the data sets and other sources for the food item list. Data sources were highly heterogeneous in respect to this, particularly because we were using both data sets and item lists from reports and publications, with the latter generally being more clustered and concise.

Clustering also appears in food composition databases.

For example, in any of these sources an item might be described as:

Cheese
Cheese, semi-hard
Cheese, Edam- or Gouda-style
Cheese, Edam
Cheese, Edam, 30% fat, 60% dry matter

When the level of clustering differs between item lists and food composition data, the task of matching items to food composition requires either:

- Selection of a generic item, if available;
- Selection of a representative food in the food composition database; or
- Creation of an average item by averaging across several foods in the food composition database

For example, the US FNDDS database includes an item 'Cheese, NFS', to which US survey data can be matched when the dietary recall respondent reports 'cheese' with no further specification.

Item clustering in food pattern modeling exercises

In food pattern modeling, item clustering is also used as a form of data reduction, because the highest level of specificity would generally not be useful in the modeling. For example, in the US food pattern modeling exercise, refined grain food items were grouped into 20 item clusters (2020 Dietary Guidelines Advisory Committee and Food Pattern Modeling Team 2020), with all white bread clustered in one item, all white rice clustered in one item, etc.

In the US example, rich data are available to inform item clustering and selection of food composition data for matching. National dietary intake data could be used to identify rarely consumed items – which were then be grouped with similar items – and to select the best 'representative item' for each item cluster.

Because we lacked such data at global level to inform clustering decisions, we were conservative in our item clustering. We clustered items in source data sets only when this made the difference between representation for a food, or not. For example, since we excluded foods consumed by fewer than 5% of children, if mangos were differentiated by variety and each variety was consumed by fewer than 5% none would be listed for the data set food item list. In this case, we clustered items so that the food would be represented.

We used this type of item clustering more frequently in the data sets with highly specific food item descriptions. This was also a partial solution to the problem of the high heterogeneity in the level of specificity across sources.

The second way we used clustering was during matching. Clustering is implicit when a food is poorly specified, and no generic item is available. In some cases, we judged that a representative item could be selected. For example, for 'Rice, white', we selected long-grain white rice, effectively creating a cluster. In other instances, we created average items (documented below), which is another form of clustering. For certain items (also documented below), we matched to an unspecified item and did not match to nutrient composition data, since we had no basis for doing so.

Special issues with matching food items consumed to food composition data
This section documents:

- Approach to matching dairy foods
- Approach to matching fish
- Approach to matching oils
- Average items we calculated from multiple rows in food composition databases
- Generic items, and selection of food composition data for these

Approach to matching dairy foods

Milk
As in the US food pattern modeling exercise, all fluid milk was matched to whole milk. We selected nutrient composition values for unfortified whole milk, 3.5% milk fat, from the German food composition database.

Yogurt and fermented milk products
In the US food pattern modeling exercise, all yogurts were matched to low-fat, unsweetened varieties. However, in the context of Optifood modeling, this could result in the model selecting yogurt rather than fluid milk, since the yogurt could provide certain nutrients at a lower calorie 'cost' (and total calories are constrained).

To avoid this complication, we matched yogurts to full-fat, unfortified varieties in the US and German food composition databases (for example, 'regular' and Greek-style full-fat yogurts). However, buttermilk is naturally low in fat and was matched as such.

Cheese
There were several challenges in selecting appropriate food composition data for cheeses. There are a very wide variety of cheeses, globally, but cheeses were commonly very poorly described in intake data sets and food item lists from publications. Second, the US food composition database generally does not specify if nutrient values for cheese reflect the use of fortified milk, or not. It was not always straightforward to determine this from nutrient values in the database.

Because the German food composition database offered generic items for hard, semi-hard, semi-soft, and soft cheese, and because milk is generally unfortified in Germany, we matched to these when descriptions allowed. We matched to specific cheeses in the US SR28 that were determined to be unfortified, when it was feasible to make this distinction.

Approach to matching fish
Correctly matching fish was the biggest challenge, among all the food groups. There is a staggering variety of fish, and nutrient content varies not only by species, but by environment. Further, common names of fish – which may appear in dietary intake data sets as well as in food composition databases – can refer to a wide variety of different species. We matched fish where possible, but many fish could only be matched to several 'unspecified codes', listed below.

Approach to matching oils
Cooking oils are often poorly described in dietary data sets and resulting food item lists. Often, respondents cannot report the type of oil used or may report only a brand name. For cases where we had no information on the types of oil in a country's food item list, we used data from FAO to create a short list of cooking oils for the country.

Specifically, we accessed data for the most recent available year (2019) from FAO's Corporate Statistical Database (FAOSTAT) at https://www.fao.org/faostat/en/#data/FBS (accessed 5 January 2022). We examined the food supply quantity in kg/cap/year and identified oils that accounted for at least 20% of the total. In most cases, this yielded a list of one to three oils. These oils were substituted for unspecified oils, when developing the nutrient profile for the subgroup 'other oils'.

Average items
Average items were calculated for two situations. In a small number of cases, we created average items because item descriptions did not align with a single food item in the food composition databases but were sufficient to narrow the choice to one of several foods, as shown in Table A5.4. For each item consumed, average items were created by averaging nutrient values from multiple items in the source database, as indicated.

Table A5.4 Average items for partially specified food items

Item consumed	Item as in database	Source database
Maize, whole grain	Corn grain, yel	USDA SR28
	Corn grain, white	USDA SR28
Maize meal, whole grain	Cornmeal, whole-grain, yel	USDA SR28
	Cornmeal, whole-grain, white	USDA SR28
Maize flour, whole grain	Corn flr, whole-grain, yel	USDA SR28
	Corn flr, whole-grain, white	USDA SR28
Maize meal, refined	Cornmeal, degermed, unenr, yel	USDA SR28
	Cornmeal, degermed, unenr, white	USDA SR28
Maize flour, refined	Corn flr, yel, degermed, unenr	USDA SR28
	Values for refined white maize flours unavailable; see explanation below the table	
Wheat, whole grain	Wheat, hard red spring	USDA SR28
	Wheat, hard red winter	USDA SR28
	Wheat, soft red winter	USDA SR28
	Wheat, hard white	USDA SR28
	Wheat, soft white	USDA SR28
Wheat flour, whole grain	Wheat flr, whole-grain	USDA SR28
	Wheat flr, whole-grain, soft wheat	USDA SR28
Corn, sweet	Corn, swt, yel, ckd, bld, drnd, wo/salt	USDA SR28
	Corn, swt, white, ckd, bld, drnd, wo/salt	USDA SR28
Peppers, sweet	Peppers, swt, grn, ckd, bld, drnd, wo/salt	USDA SR28
	Peppers, swt, red, ckd, bld, drnd, wo/salt	USDA SR28
Pomfret	Pomfret, black, steamed	ASEAN
	Pomfret, silver, steamed	ASEAN

For refined maize flour, color unspecified, we needed values for both yellow and white maize flour, degermed and unenriched. Values were only available for yellow flour. However, all USDA maize items were reviewed, and yellow and white forms were identical except for vitamin A, which was 'zero' for all forms of white maize (grains, meal, whole-grain flour, etc.). We therefore created an average value by accepting nutrient values for degermed yellow maize flour and dividing the vitamin A value by two.

We also created average items for the most commonly consumed types of meat. These items were sometimes specified in source data sets but often were not, depending on the level of clustering and the level of detail provided. In the US food pattern modeling exercise, a single SR code was selected for each type of meat. We followed that example in using the same nutrient values for all types of beef, all types of pork, lamb etc.

However, rather than selecting a single item we derived average nutrient values across sets of selected SR items, as described below. In addition, while the US modelers selected dry cooked items (for example, roasted), perhaps because they tend to be lower in fat, we judged that in most contexts meat prepared for infants and young children (IYC) is wet cooked (boiled, stewed, braised, etc.) to soften the meat. Therefore, we used the following steps to create average items for certain types of meat, where the US SR contains numerous possibilities:

1. We started with the full SR database, and
    a. Coded meats into subgroups;
    b. Dropped organ meats, processed meats, and items that were identified as separable or intermuscular fat;
    c. Coded cooking methods, and further coded to group wet cooking methods (boiled/simmered/braised/stewed), dry cooking methods (roasting, broiling etc.), frying, and others;
2. We selected wet-cooked items, but in cases where there were no wet-cooked options we used dry-cooked (roasted or broiled) items (vs. raw or fried in fat);
3. Among the selected set of items, we identified lower fat items;
    a. For beef and ground beef, we selected lean items (<10% fat);[26]
    b. For other types of meat, we identified lean items as those below the median total fat for the group (for example, below median fat for all braised pork items);
4. We then created average items by averaging all nutrients across this set of lower fat items;

Average items created by this method included those for:

- Beef, average of 53 items
- Ground beef, average of 9 items
- Pork, average of 12 items
- Lamb, average of 17 items
- Veal, average of 12 items
- Chicken, average of 15 items
- Turkey, average of 14 items

Generic items, and selection of food composition data for these
When items could not be matched to specific foods, we matched to one of the generic items in **Table A5.5.** In most cases, no nutrient values were associated to the generic (unspecified) items. However, for a few foods, food composition databases included values for certain unspecified foods, as indicated in the table.

[26] The USDA defines lean beef as containing less than 10 grams of fat per 100 grams, with additional criteria for saturated fat and cholesterol. We applied only the criterion for total fat.

Table A5.5 Generic items

Generic item	Source for nutrient values
Cereal, breakfast, whole grain, other or unspecified	No nutrient values
Infant cereal, whole grain, other or unspecified	No nutrient values
Cereal, unspecified	No nutrient values
Infant cereal, unspecified	No nutrient values
Whole grain bread and rolls, wheat or unspecified	Germany[a]
Starchy roots, tubers and pulps, other or unspecified	No nutrient values
Berries, unspecified	No nutrient values
Citrus fruit, unspecified	No nutrient values
Fruit, unspecified	No nutrient values
Dark green leaves, other or type unspecified	No nutrient values
Vegetable, unspecified	No nutrient values
Cheese, hard, other or type unspecified	Germany[a]
Cheese, semi-hard, other or type unspecified	Germany[a]
Cheese, semi-soft, other or type unspecified	Germany[a]
Cheese, soft, other or type unspecified	Germany[a]
Cheese, other or type unspecified	No nutrient values
Beans, mature, raw, type unspecified	No nutrient values
Nuts, type unspecified	No nutrient values
Poultry, type unspecified	No nutrient values
Winged game, unspecified, cooked	France
Small fish, dried/smoked, type unspecified	No nutrient values
Small fish, fresh, type unspecified	No nutrient values
Fatty fish, dried/smoked, type unspecified, size unspecified	No nutrient values
Fatty fish, fresh, type unspecified, size unspecified	No nutrient values
Fish, type unspecified	No nutrient values
Large fish, dried/smoked, type unspecified	No nutrient values
Large fish, fresh, type unspecified	No nutrient values
Lean fish, dried/smoked, type unspecified, size unspecified	No nutrient values
Lean fish, fresh, type unspecified, size unspecified	No nutrient values
Vegetable oil, other or type unspecified	No nutrient values

[a] All nutrient values were from the German national food composition database, except for choline, which was imputed in from the US SR28 for similar items, because the German database does not include this nutrient.

Handling of missing values for nutrient data, and documentation of imputation
With few exceptions, we ignored missing values for nutrient data (that is, allowed them to remain as missing) and calculated the subgroup nutrient profiles based on all items with nutrient values for any given nutrient.

Exceptions – items for which we imputed values – arose in cases where a food subgroup had few items, and missing values would result in few or no nutrient values for the subgroup for one or more nutrients. Similarly, if a particular food item was heavily 'weighted' within a subgroup, lack of nutrient values was more problematic. In general, imputations were on a dry matter basis, except as noted.

1. We imputed choline from SR28 for unfortified items from the German food composition database (that is, for milk, breads, cornflakes, yogurt, and cheese) whenever suitable matching items could be found in SR28.
2. We imputed several nutrients for four small fish, because the number of items with any nutrient values in this subgroup was small. Specifically, we imputed:
    a. Dried, stewed omena – we imputed fatty acids and tryptophan from dried omena in the same (Kenyan) food composition database (fatty acids were imputed based on total fat, rather than dry weight; tryptophan was imputed as a percent of total protein)
    b. Usipa – we imputed fatty acids from Jimenez et al. (2015); imputation was on the basis of food weight, because data on fat and water content were not available
    c. Dried/smoked, boiled anchovy – we imputed tryptophan from SR28, based on percent of total protein
    d. Dried and fresh kapenta – we imputed calculated energy from macronutrient content
3. For fortified items and unhealthy food items, we imputed all missing values because these were either single items or averages of 2-3 items, and any missing values would be problematic. We describe selection of items and of nutrient values for these foods below.

Additional rare exceptions arose when we judged specific food composition data values to be implausible; in these cases, we imputed in nutrients from a similar item on a dry matter basis.

Selection of nutrient values for unhealthy foods and beverages and fortified items

Sentinel unhealthy foods and beverages
All four types of unhealthy foods and beverages were consumed in most countries for which we had data (see Table A3.1). In general, the most-consumed group was the sweet bakers' confections, particularly various types of sweet biscuits. In most countries, salty and fried snack foods were the next most common, with crisps (potato, cassava, corn), fast food French Fries and other deep-fried starchy snacks, and salty crackers being among the most common items. Among the sweet beverages, sweetened juice drinks and carbonated drinks were approximately equally common, and sweet tea was very common in some countries. Various types of sugar confections (candies) tended to be less commonly consumed in most countries than items in the other subgroups, and no one type dominated.

Rather than matching hundreds of items to food composition data, we purposively selected several sentinel items (Table A5.7) and averaged across these to create nutrient profiles for commonly consumed subgroups.

For sweet beverages, we selected two items from the SR28 database and averaged across them. For bakers' confections, we selected and averaged across three of the plainer biscuit items from the New Zealand food composition database (13th edition), because New Zealand generally has had a less fortified food supply than the US, and did not have mandatory wheat flour fortification until 2021.[27]

We used SR28 values for potato crisps/chips. We used the New Zealand food composition database for nutrient values for corn chips due to fortification in the US, and for cassava crisps/chips, due to missing values for the US SR item.

Table A5.7 identifies the specific items we averaged across, and their nutrient data sources.

Table A5.7 Sentinel unhealthy foods and beverages

Subgroup	Sentinel item	USDA SR28 code	New Zealand 13th ed.
Sweet beverages	Juice drink	14645	
	Soda	14148	
Bakers' confections	Biscuit, arrowroot		A146
	Biscuit, malt		A64
	Biscuit, cream filling		A9
Crisps/chips	Potato crisps/chips	19411	
	Cassava crisps/chips		U1023
	Corn chips		U1016

Imputations
For sweet beverages, data were complete except for specific fatty acids and amino acids; we imputed these as '0' as there were values of '0' for protein and PUFA. For all items with nutrient values from the New Zealand food composition database, there were no nutrient values for magnesium, copper, choline, or tryptophan. These values were imputed on a dry matter basis from similar items in the US SR database. In one case, values were also unavailable in the US SR; this value was left as missing (choline for one item) and averaged across other items.

[27] See: https://fortificationdata.org/list-of-countries-for-the-food-fortification-dashboard/, accessed 7 March 2022.

Fortified items

As noted in Section 2b.1.4, The GDG requested modeling with three types of fortified items: multiple-micronutrient powders (MNPs), small-quantity lipid-based nutrient supplements (SQ-LNS), and fortified infant cereals. For the first two we determined the nutrient content of items as currently used by UN agencies. For the last, there are a very large number of commercially available infant cereals, but since fortification levels vary widely across brands, countries, and products, we chose to model with a common food aid commodity targeted to IYC, Super Cereal Plus.

Nutrient content of these three products is specified, sometimes in ranges, and specifications do not cover all our nutrients of interest. For some nutrients in SQ-LNS and Super Cereal Plus, we imputed values based on the food ingredients. Data sources, all accessed 4 January 2022, were:

MNPs: The UNICEF supply catalogue, https://supply.unicef.org/s0000225.html.

SQ-LNS: World Food Programme. *Technical Specifications for Lipid-based Nutrient Supplement - Small Quantity LNS-SQ. Commodity code: MIXLNS010. Version: 1, adopted 2019.* See Table 2. https://docs.wfp.org/api/documents/WFP-0000106806/download/. This same formulation will be adopted by UNICEF soon.[28]

Super Cereal Plus: USAID. USAID Commodity Specification Super Cereal Plus. For Use in International Food Assistance Programs. Effective Date: March 3, 2016. https://www.usaid.gov/sites/default/files/documents/1866/USAID_SCP_Specification.pdf. Micronutrients are targets from Table 2; protein and fat, minima from Table 4; crude fiber, ash and moisture, maxima from Table 4; energy is from product specifications page 3.

Imputations for MNPs

For MNPs, all nutrients not specified in the formula are presumed to be absent and values of zero were entered in the food composition database. We note that some of these values may not be true 'zeros' (for example, water) but this would not have affected our analyses.

Imputations for SQ-LNS

For SQ-LNS, there is no 'recipe' available, that is, neither the gram quantity nor percent-by-weight for ingredients are in the specifications. The WFP specifications provide ranges rather than single values for energy and macronutrients; for these, we used values from Arimond et al. (2015). We imputed values for three nutrients of interest for which there are no specifications: carbohydrate, fiber, and choline. We also imputed a value for tryptophan, so we could calculate niacin equivalents.

Carbohydrate: We estimated approximate energy from protein and fat based on Atwater factors of 4 and 9, respectively. We estimated approximate energy from carbohydrate by subtraction, and grams of carbohydrate using the Atwater factor of 4.

Fiber: We considered peanut to be the only source of fiber and dry milk powder and peanut to be the only sources of protein, since we lacked information on quantities for other ingredients (for example, whey powder, vegetable fat). We used selected USDA SR data for nutrient composition (SR 01091 for nonfat dry milk powder; SR 16390 for peanut). While the recipe for LNS is not available, information on grams of dry milk powder is available (Kumordzie et al. 2019). Using this information, we:

1. Estimated the amount of protein from dry milk powder;
2. Estimated the amount of protein from peanut by subtraction from the total protein value in Arimond et al. (2015);
3. Back-calculated grams of peanut; and
4. Identified fiber content based on this estimate of grams of peanut.

[28] Personal communication from Grainne Mairead Moloney (UNICEF) to the Home Fortification Technical Advisory Group, June 29, 2021. WFP formulation provided to us by Kathryn Dewey.

Choline: We considered dried skim milk powder and peanut to also be the only sources of choline. We summed choline for these two sources based on the gram amount of milk powder and back-calculated gram amount of peanut in the SQ-LNS.

Tryptophan: the value for tryptophan was provided by a manufacturer (Nutriset, Maulaney, August 2020) to K. Dewey, a GDG member, who subsequently provided it to us.

Imputations for Super Cereal Plus
The USAID document cited above provides specifications for most macronutrients and for ingredients as percent by weight. We imputed carbohydrate by subtraction, using the specifications for minimum percent protein and fat, and maximum percent water, crude fiber and ash. To impute values for choline, tryptophan, copper, magnesium, and fatty acids, we selected USDA SR28 values (below) for each ingredient, and then summed the nutrient content of the ingredients to derive estimates.

Ingredient	**USDA SR28 code**
Corn grain	20314 (all nutrients except choline, which was missing) 20320 (choline)
Soybeans, roasted	16410
Milk, dry, non-fat	01091
Sugars, granulated	19335
Oil, soybean, refined	04669

Citations for all food composition databases

Databases are included here if we employed them when searching for food composition data, even if ultimately, they were not used. They are listed in the following order:

- Primary USDA sources
- Global databases
- Regional databases
- National databases
- Project databases

USDA

United States Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28 (Slightly revised). Version Current: May 2016. http://www.ars.usda.gov/ba/bhnrc/ndl

United States Department of Agriculture, Agricultural Research Service. 2018. USDA Food and Nutrient Database for Dietary Studies 2017-2018. Food Surveys Research Group Home Page, http://www.ars.usda.gov/nea/bhnrc/fsrg

United States Department of Agriculture (USDA), Agricultural Research Service. FoodData Central: Foundation Foods. Version Current: October 2021. Internet: fdc.nal.usda.gov. *Used only for imputations for nutrients in white rice flour, and accessed in the interactive online version at*: https://fdc.nal.usda.gov/index.html

Global

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Regional

West Africa

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Institute of Nutrition, Mahidol University (2014). ASEAN Food Composition Database, Electronic version 1, February 2014, Thailand. URL:http://www.inmu.mahidol.ac.th/aseanfoods/doc/ASEAN_FCD_V1_2014.pdf

National

Australia

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Annex 6 Further details of nutrient profiles

We developed nutrient profiles for each food subgroup, as described in Section 2b.3. After developing draft nutrient profiles, we reviewed them to identify any undue influence of nutrient outliers within each food subgroup.

Examining draft nutrient profiles for food subgroups
For each target and non-target nutrient and for each food subgroup, we sorted nutrient values from lowest to highest and examined:

- The range for the nutrient across all food items in the subgroup
- The percent difference between the mean and the median
- The percent of values which would be excluded based if a criterion of +/- 2 standard deviations from the mean was applied
- The percent difference between the mean without exclusions and the mean with exclusions based on +/- 2 standard deviations

We were conservative in making changes, since in many cases outliers may be real and true. However, we made changes when:

- Outliers were extreme and had too much impact on means
- The source food composition database was one we had less trust in
- An item was a clear 'misfit' in a group, nutritionally

Each of these was rare. For these few cases we chose to either 1) replace nutrient values with values from an alternate food composition database, 2) set a specific nutrient value to missing, or 3) exclude an item.

We considered high heterogeneity in certain subgroups to be real and as requiring further division of the subgroups. Liver from several mammals and birds consistently had very high values for vitamin A and several other nutrients compared to other organ meats; because of this, we narrowed our group for modeling purposes to liver. Seafood items contributed very high outliers for several nutrients, compared to fish. Seafood, as a group, were also highly heterogeneous in nutrient content. Since fish were far more widely consumed than seafood, and to avoid the influence of outliers, we narrowed our group for modeling purposes to fish.

Following refinements, as a final check we computed nutrient densities (per 1000 kcal), sorted by the density variables for macronutrients, fiber and micronutrients, and examined these per each food group.

Calculating nutrient profiles
After addressing outliers, final nutrient profiles were calculated as weighted means, where the weights were the number of countries where a given food item was reported to be consumed. Data were available for 38 countries.

Table A6.1 shows the number of food items reported to be consumed in each of the countries, after exclusions and clustering. **Table A6.2** shows the food items included in calculating the profiles, along with the weights. The resulting nutrient profiles are presented in Tables 8 and 9 (Section 2b.3) for target nutrients. **Tables A6.3-A6.4** provide nutrient profiles for the non-target nutrients.

In Table A6.2, we include unspecified items for which nutrient values could not be assigned (and which therefore did not contribute to nutrient profiles). They are included to illustrate the high proportion of unspecified items in certain subgroups (for example, refined breakfast cereals, and fish). These items are italicized.

Table A6.1. Number of food items reported to be consumed by infants and young children, by country

Country	# items	Country	# items
Australia	36	Korea	74
Bangladesh	43	Lao PDR	32
Brazil	30	Malawi	31
Bulgaria	50	Mexico	60
China	94	Nepal	36
Colombia	53	New Zealand	38
Czech Republic	29	Nigeria	36
DRC	34	Pakistan	36
Ecuador	47	Panama	23
Ethiopia	48	Peru	40
Europe[a]	82	Portugal	57
France	100	Singapore	61
Germany	46	South Africa	16
Ghana	48	Tanzania	26
Guatemala	55	Thailand	33
India	23	UK	60
Indonesia	54	US	57
Jamaica	28	Vietnam	67
Kenya	66	Zambia	19

[a] Food item list from a multi-country study with sites in Belgium, Germany, Italy, Poland, and Spain.

Table A6.2. Food items and weights used to develop food subgroup nutrient profiles[a]

Food groups and subgroups	# countries (weights)
Starchy staple foods	
Whole grains	
All nutrient values for raw/dry forms, retention-adjusted	
Amaranth	1
Barley flour	1
Barley, hulled	6
Barley, pearled	2
Buckwheat	1
Bulgur	2
Maize flour, whole grain white	6
Maize flour, whole grain, color unspec	6
Maize flour, whole grain, yellow	2
Maize meal, whole grain, white	1
Maize, meal, whole grain, color unspec	3
Maize, whole grain, color unspec	1
Maize, whole grain, white	4
Maize, yellow, masa/dough, with calcium hydroxide(lime), dry[b]	1
Masa flour, whole grain, white, unenriched, high calcium[b]	2
Millet flour	3
Millet	6
Rice, black or brown, non-glutinous	1
Rice, brown, glutinous	1
Rice, brown, long-grain	4
Sorghum (guinea corn)	3
Sorghum (guinea corn), flour, whole-grain	4
Teff, raw (grain or flour)	1
Wheat flour, whole grain, hard or soft	5
Wheat varieties, hulled (farro, spelt, emmer, einkorn)	1
Wheat, whole grain, type unspecified	1
Refined grains	
All nutrient values for raw/dry forms, retention-adjusted	
Cornstarch[c]	5
Maize flour, degermed, unenriched, color unspec	1
Maize flour, degermed, unenriched, yellow	2
Maize flour, white, highly refined (Malawi)	1
Maize flour, white, intermediate extraction or NS (Malawi)	3
Maize flour, white, refined (Zambia)	4
Maize grain, hulled, white	1
Maize meal, degermed, unenriched, color unspec	4
Maize meal, degermed, unenriched, white	1
Pasta, white	24
Rice flour, white	7
Rice noodles	4
Rice, white, glutinous	4
Rice, white, long-grain	33

Food groups and subgroups	# countries (weights)
Rice, white, medium-grain	2
Rice, white, short-grain	1
Semolina	6
Wheat flour, refined, white, unenriched	16
Wheat starch[c]	1
Whole grain breakfast cereals	
All nutrient values for raw/dry forms, retention-adjusted if applicable	
Cereal, breakfast, whole grain, other or unspecified	*1*
Infant cereal, whole grain, other or unspecified	*1*
Oats	13
Whole oat RTE cereals	1
Whole wheat RTE cereals	4
Refined grain breakfast cereals	
All nutrient values for raw/dry forms, retention-adjusted if applicable	
Baby cereal, semolina	1
Baby cereal, sorghum, refined	1
Baby cereal, white rice	1
Cereal, unspecified	*5*
Corn flakes	2
Farina, cereal	1
Infant cereal, unspecified	*15*
Whole grain bakery products	
All nutrient values for form as consumed, 'as is'	
Bread, chapati or roti, whole wheat	2
Bread, corn, leavened	1
Bread, corn, unleavened	1
Bread, paratha, whole wheat	1
Bread, sorghum, leavened	1
Bread, sorghum, unleavened	1
Tortilla, maize[b]	4
Injera, maize, fermented	1
Injera, millet, fermented	1
Whole grain bread and rolls with wheat germ	1
Whole grain bread and rolls, multigrain	1
Whole grain bread and rolls, rye	2
Whole grain bread and rolls, spelt	1
Whole grain bread and rolls, wheat or unspecified	8
Refined grain bakery products	
All nutrient values for form as consumed, 'as is'	
Chapati or roti, refined flour	3
Paratha, refined flour	1
Tortilla, refined wheat flour	2
White bread and rolls	30

Food groups and subgroups	# countries (weights)
Starchy roots, tubers, plantains	
Nutrient values for form as indicated, raw items retention-adjusted	
Arrowroot, raw	1
Breadfruit, raw	1
Cassava (Tapioca) (incl. white yam), raw	9
Cassava flour, boiled/dough	2
Cassava, fermented paste (fufu, wet)	1
Cassava, grated, toasted (gari), raw	1
Green banana flour, raw	2
Plantains (incl. green banana), cooked	8
Potatoes, boiled	30
Sago flour, raw	1
Starchy roots, tubers and pulps, other or unspecified	*2*
Sweet potato, white, boiled	10
Tapioca, pearl, raw	2
Taro, cooked	1
Vitamin A-rich fruits	
Nutrient values for raw forms, except where indicated	
Apricot, cooked or canned	1
Apricot	5
Cantaloupe	2
Lucuma fruit	1
Mango, cooked or canned	2
Mango	16
Papaya	15
Passion Fruit	3
Persimmons, Japanese	2
Tamarillo (tree tomato)	2
Berries	
Nutrient values for raw forms, except where indicated	
Berries, unspecified	*3*
Blackberries, cooked or canned	1
Blackberries	1
Blueberries, cooked or canned	1
Blueberries	2
Currants (red or white)	1
Raspberries (incl. black & red)	1
Strawberries, cooked or canned	2
Strawberries	8
Citrus	
All nutrient values for raw forms	
Citron (limon real)	1
Citrus fruit, unspecified	*2*
Grapefruit	1
Oranges	22
Tangerine	10

Food groups and subgroups	# countries (weights)
Vitamin C-rich fruits	
All nutrient values for raw forms	
Guava	7
Jujube	1
Kiwifruit	6
Lychee	1
Bananas	
Nutrient values for form as indicated	
Bananas, cooked or canned	3
Bananas, raw	33
High-fat fruits	
All nutrient values for raw forms	
African pear (ube, eben)	1
Avocado	9
Coconut meat	4
Other fruits	
Nutrient values for raw forms, except where indicated	
Apples, cooked or canned	5
Apples	24
Applesauce	5
Casaba melon	1
Cherries	4
Figs, fresh	1
Fruit, unspecified	*4*
Grapes, cooked or canned	1
Grapes	13
Japanese pears	1
Mangosteen	1
Naranjilla	1
Nectarine	1
Peaches, cooked or canned	2
Peaches	7
Pears, cooked or canned	3
Pears	11
Pineapple	5
Plums	1
Pomegranate	3
Quinces	1
Rambutan	1
Roseapple	1
Watermelon	8

Food groups and subgroups	# countries (weights)
Dark green leafy vegetables	
Nutrient values for boiled forms, except where indicated as raw, or as raw values with retention adjustments (when cooked forms were not available)	
Amaranth leaves	5
Bak choy (Chinese cabbage)	3
Baobab leaves	1
Bean leaves	1
Broccoli, Chinese, raw, retention-adjusted	1
Cassava leaves	3
Chard	4
Chrysanthemum leaves, raw, retention-adjusted	1
Cocoyam leaves	1
Cowpea leaves	1
Dark green leaves, other or type unspecified	*9*
Endive, raw	2
Escarole	2
Fiddlehead ferns, raw, retention-adjusted	1
Gnetum africanum (wild spinach, afang) leaves	1
Heinsia crinita (atama) leaves, raw, retention-adjusted	1
Jute leaves	2
Kale	4
Lamb's lettuce (mache), raw	1
Lasianthera africana (editan) leaves	1
Malabar spinach	1
Mustard greens (Incl. dandelion and poke greens)	5
Nightshade leaves/hierbamora	3
Okra leaves	1
Pumpkin leaves	5
Romaine lettuce, raw	4
Roselle/hibiscus/bra leaves	1
Sauropus leaves, raw, retention-adjusted	1
Seaweed (laver), raw, retention-adjusted	1
Shepherd's purse leaves, raw, retention-adjusted	1
Spinach	15
Swamp cabbage (water convovulus)	2
Sweet potato leaves	1
Tamarind leaves, young, raw, retention-adjusted	1
Turnip greens	2
Watercress (Incl. thistle leaves), raw	2
Waterleaf (Ceylon spinach)	1
Other brassicas	
All nutrient values for boiled forms	
Broccoli (incl. broccoli raab, Chinese broccoli)	16
Brussels sprouts	1
Cauliflower (Incl. broccoflower)	12
Green cabbage	13

Food groups and subgroups	# countries (weights)
Vitamin A-rich orange vegetables	
All nutrient values for boiled forms	
Carrots	27
Pumpkin, flesh	15
Sweet potato, yellow/orange	10
Winter squash	8
Peppers and tomatoes	
Nutrient values for form as indicated	
Green peppers (sweet, bell), boiled	4
Green peppers (sweet, bell), raw	3
Peppers, (sweet, bell), boiled, color unspec	7
Red peppers (sweet, bell), boiled	5
Tomatoes, red, cooked	13
Tomatoes, green, raw	1
Tomatoes, red, raw	30
Yellow peppers (sweet, bell), raw	1
Peas and beans (immature pods)	
Nutrient values for boiled forms except for one raw item, retention-adjusted	
Angle beans/winged beans, young pods, raw	1
Broadbeans, immature seed	1
Cowpeas, field peas, blackeye peas, pigeon peas	2
Edible-pod green peas (Incl. snowpeas)	3
Green beans (Incl. snap and yellow beans)	11
Green peas	13
Kidney beans, immature	2
Yardlong bean	1
Other vegetables	
Nutrient values for boiled forms, except where indicated as raw, or as raw values with retention adjustments (when cooked forms were not available)	
Artichoke	2
Asparagus	4
Beets	4
Bitter gourd	2
Calabash	1
Cardoon	1
Celery	10
Chayote, fruit	3
Chayote, fruit, raw	1
Corn, sweet, color unspec	6
Corn, sweet, white	1
Corn, sweet, yellow	6
Cucumber, raw	10
Eggplant	8
Endive, Belgian (witloof chicory), raw	2
Fennel, bulb, raw, retention-adjusted	2
Gourd, ivy, raw, retention-adjusted	1

Food groups and subgroups	**# countries (weights)**
Gourd, pointed (palwal)	1
Gourd, wax, all varieties, raw, retention-adjusted	1
Jerusalem artichoke, raw, retention-adjusted	1
Leeks	5
Lotus root	2
Mungbeans sprouts	3
Mushrooms	6
Okra	3
Onions	28
Parsnips	1
Patty-pan squash	1
Radish, daikon	2
Radish, raw	2
Rutabaga	2
Salsify	1
Soybean sprouts, steamed	1
Spring onions/scallions, raw	5
Summer Squash, yellow and zucchini (Incl. spaghetti squash, bitter and winter melons)	10
Turnips	4
Vegetable, unspecified	*2*
Waterchestnuts, canned	1
Milk	
Nutrient values for fresh, fluid	
Milk, Indian buffalo	4
Milk, camel	1
Milk, goat	5
Unflavored cow milks, 1% (matched to whole cows milk)	2
Unflavored cow milks, 2% (matched to whole cows milk)	5
Unflavored cow milks, fat-free (matched to whole cows milk)	1
Unflavored cow milks, whole	36
Yogurt	
Buttermilk	1
Greek yogurt, unflavored, whole and unspecified (matched to whole)	1
Unflavored Yogurts, fat-free (matched to whole)	1
Unflavored Yogurts, whole and unspecified (matched to whole)	26
Unflavored Yogurts, lowfat (matched to whole)	6
Cheese	
Cheese, cheddar	4
Cheese, feta	1
Cheese, fresh (queso fresco)	4
Cheese, gouda	1
Cheese, hard, other or type unspecified	3
Cheese, mozzarella	3
Cheese, other or type unspecified	*8*
Cheese, semi-hard, other or type unspecified	3

Food groups and subgroups	# countries (weights)
Cheese, semi-soft, other or type unspecified	5
Cheese, soft, other or type unspecified	6
Cottage cheese, full fat	1
Cream cheese	2
Eggs	
Nutrient values for form as indicated, raw items retention-adjusted	
Eggs, chicken, boiled	35
Eggs, duck, raw	3
Eggs, guinea fowl, boiled	1
Eggs, quail, raw	4
Legumes	
All nutrient values for raw/dry forms, retention-adjusted	
Adzuki beans, mature	1
Beans, mature, type unspecified	*14*
Beans, small white, mature	4
Black beans, mature	4
Broad bean (fava) flour	1
Broadbeans/fava, mature	1
Chickpea flour	1
Chickpeas, mature	5
Cowpeas, all types, mature	7
French beans, mature	1
Gram flour, black gram (mungo)	1
Kidney beans, mature	8
Lentils	10
Lupin seed, mature	1
Mung beans, mature	5
Mungo beans/black gram, mature	3
Peas, mature	7
Pigeon peas, mature	3
Pinto beans, mature	3
White beans, large, mature	1
Soy foods[d]	
All nutrient values for cooked/wet form	
Soybean flour, full fat	4
Soybeans/edamame	6
Tofu (high calcium coagulant)	6
Nuts and seeds	
Nutrient values for form as indicated	
Almonds, roasted, and almond butter	3
Cashews, roasted	1
Filberts/hazelnuts	1
Lotus seeds	1
Melon seeds	2
Nuts, type unspecified	*2*
Peanut butter[e]	3

Food groups and subgroups	# countries (weights)
Peanut flour, defatted	1
Peanuts, roasted	13
Pumpkin/squash seed kernels, dried	1
Pumpkin/squash seed kernels, roasted	1
Sesame butter	1
Sesame seeds	5
Sunflower seeds, roasted	1
Walnuts	3
Beef, lamb, goat, game	
Nutrient values for form as indicated, raw items retention-adjusted	
Alpaca meat, raw	1
Beef, lean, braised	27
Beef, ground, lean, baked or broiled	6
Dog meat, raw	1
Goat, roasted	3
Horse (including donkey), roasted	2
Lamb, lower fat items, braised	4
Mutton, boiled	3
Rabbit, domesticated, stewed	3
Veal, lower fat items, braised	2
Veal, ground, broiled	1
Water buffalo, roasted	1
Pork	
Nutrient values for form as indicated	
Pork, fresh, lower fat items, braised	11
Pork, ground, lower fat, broiled	3
Poultry	
Nutrient values for form as indicated, raw items retention-adjusted	
Chicken, lower fat items, stewed or braised	28
Duckling, braised	4
Goose, roasted	1
Poultry, type unspecified	*1*
Squab (pigeon), raw	1
Turkey, lower fat items, roasted	2
Winged game, unspecified, cooked	1
Liver	
Nutrient values for form as indicated	
Beef liver, braised	6
Chicken liver, simmered	6
Pig liver, braised	5
Small fish	
Nutrient values for form as indicated, raw items retention-adjusted	
Anchovy, whole, dried or smoked, simmered	4
Kapenta, dried, stewed (*Limnothrissa miodon & Stolothrissa tanganicae*)	1
Kapenta, fresh, raw (*Limnothrissa miodon & Stolothrissa tanganicae*)	1
Lake Victoria sardine (omena), stewed (*Rastrineobola argentea*)	1

Food groups and subgroups	**# countries (weights)**
Mackerel, canned, drained	2
Sardines, Atlantic, canned, drained	2
Small fish, dried/smoked, type unspecified	*4*
Small fish, fresh, type unspecified	*3*
Usipa, dried, boiled (*Engraulicypris breianalis*)	1
Usipa, fresh, raw (*Engraulicypris sardella*)	1
Larger fish	
Nutrient values for form as indicated, raw items retention-adjusted	
Atlantic horse mackerel, steamed	1
Carp, cooked, dry heat	2
Catfish, cooked, dry heat	4
Chub, pale, raw	1
Cod, cooked, dry heat	2
Cod, Atlantic, cooked, dry heat	1
Cutlassfish (hairtail), raw	1
European hake, braised	1
Fatty fish, dried/smoked, type unspecified, size unspecified	*1*
Fatty fish, fresh, type unspecified, size unspecified	*1*
Fish, type unspecified	*17*
Flounder, cooked, dry heat	1
Herring, cooked, dry heat	2
Large fish, dried/smoked, type unspecified	*3*
Large fish, fresh, type unspecified	*4*
Lean fish, dried/smoked, type unspecified, size unspecified	*1*
Lean fish, fresh, type unspecified, size unspecified	*2*
Mackerel, cooked, dry heat	3
Perch, cooked, dry heat	3
Plaice, steamed	1
Pollock, Alaska, cooked (method NS in source)	1
Pomfret, Asian, steamed	1
Salmon, farmed, cooked, dry heat	2
Salmon, smoked	1
Sardine, fresh, steamed	2
Scad, raw	1
Shark, raw	1
Sheat, raw	1
Silver carp, raw	1
Snakehead, raw	3
Snapper, cooked, dry heat	1
Threadfin, all species, raw	1
Tilapia, cooked, dry heat	4
Trout, cooked, dry heat	1
Tuna, white, canned, drained (high omega-3)	1
Tuna, white, canned, drained (low omega-3)	2
Tuna, skipjack, fresh, cooked, dry heat	2
Tuna, smoked, all species	1

Food groups and subgroups	# countries (weights)
Whiting, cooked, dry heat	1
Solid fats and saturated oils	
Butter	13
Butter, anhydrous (incl. ghee)	5
Coconut oil	2
Lard, liquid/oil	2
Lard, solid	3
Margarine, reduced fat (matched to 80% fat)	5
Margarine, regular and unspecified (matched to 80% fat)	12
Palm oil	13
Vegetable shortening	4
Other vegetable oils	
Canola oil	7
Corn oil	3
Mustard oil	2
Olive oil	6
Peanut oil	3
Rice bran oil	1
Safflower oil	1
Sesame oil	1
Soybean oil	19
Sunflower oil	9
Vegetable oil, other or type unspecified	*4*

[a] For all items, preferred forms (raw, cooked, etc.) were selected from food composition databases when available (see Table A5.2) but when unavailable, other forms were selected.

[b] These nixtamalized maize products are high in calcium, but do not substantially affect the nutrient profiles for their respective subgroups (whole grains, and whole grain bakery items), due to the large number of items.

[c] These two starches were included with refined grains either because they were reported to be used to prepare simple porridges (corn starch) or appeared to be consumed in similar quantities (wheat starch); i.e., it did not appear to be used only as a thickener or minor ingredient.

[d] The representative food item for tofu is as selected by the US food pattern modeling team, and is coagulated with nigari (calcium sulfate and magnesium chloride; US SR 16126). Other items in this subgroup are lower in calcium, and the subgroup profile is intermediate.

[e] The description of the dominant item, peanut butter, in the US SR does not indicate cooking, but peanuts are usually roasted before processing into peanut butter.

Table A6.3. Non-target nutrient profiles: Macronutrients and minerals

	Protein (g)	Carbohydrate (g)	Fiber (g)	Magnesium (mg)	Phosphorus (mg)	Copper (mg)
Starchy staple foods						
Whole grains	9.6	74.9	8.9	121.2	276.8	0.38
Refined grains	8.6	78.5	2.3	28.2	111.4	0.19
Whole grain breakfast cereals	12.8	70.2	10.6	136.2	387.4	0.39
Refined grain breakfast cereals	8.6	78.5	2.3	28.2	111.4	0.19
Whole grain bakery products	6.7	45.2	7.6	63.5	201.2	0.29
Refined grain bakery products	8.3	51.3	2.9	23.6	86.0	0.20
Starchy roots, tubers, plantains	1.5	25.8	1.9	21.1	34.9	0.13
Fruits						
Vitamin A-rich fruits	0.9	13.6	2.6	14.9	18.5	0.08
Berries	0.8	9.9	2.9	12.9	21.8	0.07
Citrus	0.9	12.0	2.2	10.6	15.9	0.04
Vitamin C-rich fruits	1.8	15.0	4.1	18.4	35.9	0.17
Bananas	1.1	22.8	2.6	27.0	22.0	0.08
High-fat fruits	2.8	11.0	7.0	30.7	68.3	0.28
Other fruits	0.5	13.1	1.8	7.1	13.5	0.07
Vegetables						
Dark green leafy vegetables	2.9	5.2	2.7	45.1	52.0	0.14
Other brassicas	1.9	5.8	2.6	15.7	46.2	0.04
Vitamin A-rich orange vegetables	0.9	9.1	2.4	11.5	28.9	0.06
Peppers and tomatoes	0.9	4.7	1.1	10.3	23.2	0.07
Peas and beans (immature pods)	4.0	12.7	4.3	31.0	70.7	0.11
Other vegetables	1.5	8.2	1.9	16.5	39.7	0.09
Dairy products						
Milk	3.4	4.7	0.0	13.3	95.3	0.02
Yogurt	4.0	4.4	0.0	12.0	92.9	0.01
Cheese	20.8	1.6	0.0	23.8	381.4	0.05
Protein foods						
Eggs	12.7	1.1	0.0	10.8	184.9	0.02
Legumes	23.3	61.5	17.1	110.6	322.9	0.84
Soy foods	14.0	7.4	3.5	88.5	186.0	0.52
Nuts and seeds	22.5	21.9	8.7	243.6	533.8	1.13
Beef, lamb, goat, game	30.9	0.0	0.0	22.2	216.1	0.14
Pork	29.7	0.1	0.0	23.0	244.4	0.08
Poultry	27.2	0.0	0.0	22.4	177.5	0.09
Liver	26.6	3.2	0.0	20.4	389.2	2.84
Small fish	27.5	0.2	0.0	47.5	606.8	0.17
Larger fish	21.8	0.0	0.0	36.5	256.4	0.07
Added fats and oils						
Solid fats and saturated oils	0.3	0.2	0.0	1.4	7.2	0.00
Other vegetable oils	0.0	0.0	0.0	0.0	0.0	0.00

Table A6.4. Non-target nutrient profiles: Vitamins and fatty acids

	Niacin (mg)	NE[a] (mg)	Vit. D (μg)	LA or 18:2[b] (g)	ALA or 18:3[b] (g)
Starchy staple foods					
Whole grains	3.74	5.70	0.00	1.48	0.07
Refined grains	1.33	3.12	0.00	0.33	0.03
Whole grain breakfast cereals	2.18	5.06	0.00	1.97	0.10
Refined grain breakfast cereals	1.33	3.12	0.00	0.33	0.03
Whole grain bakery products	2.47	3.60	0.00	0.84	0.04
Refined grain bakery products	0.82	2.14	0.00	0.62	0.06
Starchy roots, tubers, plantains	0.94	1.38	0.00	0.03	0.01
Fruits					
Vitamin A-rich fruits	0.60	0.70	0.00	0.05	0.04
Berries	0.42	0.50	0.00	0.10	0.06
Citrus	0.31	0.42	0.00	0.03	0.01
Vitamin C-rich fruits	0.74	1.03	0.00	0.25	0.08
Bananas	0.66	0.81	0.00	0.05	0.03
High-fat fruits	1.37	1.75	0.00	1.27	0.08
Other fruits	0.25	0.31	0.00	0.05	0.01
Vegetables					
Dark green leafy vegetables	0.66	1.11	0.00	0.05	0.08
Other brassicas	0.42	0.82	0.00	0.04	0.10
Vitamin A-rich orange vegetables	0.55	0.77	0.00	0.06	0.01
Peppers and tomatoes	0.55	0.69	0.00	0.08	0.01
Peas and beans (immature pods)	1.22	1.78	0.00	0.07	0.05
Other vegetables	0.68	0.95	0.01	0.12	0.02
Dairy products					
Milk	0.13	0.86	0.11	0.05	0.03
Yogurt	0.09	0.84	0.06	0.09	0.06
Cheese	0.31	5.95	0.47	0.57	0.23
Protein foods					
Eggs	0.08	2.86	2.17	1.15	0.04
Legumes	1.54	5.71	0.00	0.58	0.21
Soy foods	0.57	3.68	0.00	3.24	0.42
Nuts and seeds	8.75	13.45	0.00	15.84	0.83
Beef, lamb, goat, game	4.70	9.85	0.10	0.34	0.09
Pork	8.08	14.13	0.63	0.77	0.03
Poultry	6.26	11.68	0.12	0.99	0.04
Liver	12.56	17.98	0.60	0.61	0.02
Small fish	12.47	18.80	6.05	0.99	0.19
Larger fish	4.93	9.32	4.78	0.26	0.07
Added fats and oils					
Solid fats and saturated oils	0.02	0.10	0.17	11.45	1.04
Other vegetable oils	0.00	0.00	0.00	41.81	4.13

[a] NE = niacin equivalents, calculated as mg niacin + mg tryptophan/60. Data for tryptophan are missing for ~30% of items. We examined the impact of missing values and judged that the missing values did not bias means for niacin equivalents.

[b] ALA = alpha-linolenic, LA = linoleic. Nutrient values for ALA and LA were available for slightly fewer than one-quarter of food items. We used these values when available but otherwise used values for undifferentiated 18:3 and 18:2 fatty acids, respectively.

Nutrient profiles for 'single staple' food patterns
We modeled three types of 'single staple' food patterns.

- For rice-based patterns, we selected a single item from the US food composition database, SR 20444 (*Rice, white, long-grain, regular, raw, unenriched*), because this was by far the most common rice reported across the available data sets.

  The nutrient profile is for the dry, raw form, but is adjusted for nutrient retention in the same manner as other grain items.
- For maize-based patterns, there was more diversity to choose from in the types of maize in the data sets. Given the objective of this part of the modeling was to assess nutrient gaps in monotonous diets from lower income settings, we selected a type of maize flour typical in many settings in Africa, and modeled using US SR 20316 (*Corn flour, whole-grain, white*); we did not model a high calcium, nixtamalized maize, but also did not model more refined maize flour, which tends to be more expensive in some low-income countries.

  The nutrient profile is for the dry, raw form, with adjustments for retention.
- For roots and tubers, there was also very great diversity and no item or small set of items dominated, so we chose to model with the subgroup nutrient profile for roots, tubers and plantains. The nutrient profile represents wet/cooked forms.

Nutrient profiles for these 'single staple' items are presented in tables below.

Nutrient profiles for sentinel unhealthy foods and beverages and fortified items
Food composition data for these items is described in Annex 5. We calculated nutrient profiles for the purposively selected unhealthy items as unweighted averages of the items listed in Annex 5.

In the case of fortified items, we selected only one item for each of: micronutrient powders; small-quantity lipid-based nutrient supplements; and a fortified cereal mix targeted to IYC. For each of these three items the profile is simply the nutrient content of the selected item. However, the quantity varies by product:

- For MNPs, the nutrient profile is per dose of a single 1 g sachet
- For SQ-LNS, the nutrient profile is per dose of a single 20 g sachet
- For Super Cereal Plus, the nutrient profile is per 100 grams, as there is no fixed/standard 'dose' in the specifications

Nutrient profiles for all of these are presented in **Tables A6.5 – A6.6** (target nutrients) and **Tables A6.7-A6.8** (non-target nutrients).

Table A6.5. Nutrient profiles for Optifood modeling: Energy and target minerals[a, b]

	Energy (kcal)	Fat (g)	Calcium (mg)	Iron (mg)	Potassium (mg)	Zinc (mg)
Profiles for 'single staple' models[c]						
Maize flour, whole grain, white	361	3.9	7.0	2.38	315	1.73
Rice, white, long-grain	365	0.7	28.0	0.76	109	1.09
Starchy roots, tubers, plantains	107	0.1	13.1	0.50	317	0.27
Unhealthy beverages and foods						
SSB, average	53	0.1	2.0	0.01	18	0.05
Sweet biscuit, average	444	14.6	32.0	0.47	147	0.60
Crisps and chips, average	499	27.8	63.3	1.39	529	0.96
Fortified products						
MNP – 1 g dose	0	0.0	0.0	10.00	0	4.10
SQ-LNS – 20 g dose	118	9.6	280.0	6.00	200	8.00
SCP – per 100 g[d]	410	9.0	362.0	4.00	140	5.00

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement; SSB = sugar-sweetened beverage.

[b] All values are per 100 grams, except as indicated for MNP and SQ-LNS.

[c] Nutrient values for grains are for raw/dry forms, after applying USDA retention adjustments for boiled, steamed maize flour and rice cooked with water. Nutrient values for roots/tubers/plantains are as shown in Table A6.2, for wet/cooked forms or raw forms with retention adjustments.

[d] The specifications indicate SCP should have either 4 mg ferrous fumarate or 2.5 mg iron-sodium EDTA (see SCP specifications at: https://www.usaid.gov/sites/default/files/documents/1866/USAID_SCP_Specification.pdf). We used the value for ferrous fumarate because the specifications for MNP and SQ-LNS indicate a mix of forms but with the majority of iron as ferrous iron, so we considered the value for ferrous iron for SCP to provide a better comparison.

Table A6.6. Nutrient profiles for Optifood modeling: Target vitamins and choline[a, b]

	Vit. A (µg RE)	Thiamin (mg)	Riboflavin (mg)	Vit. B6 (mg)	Folate (µg DFE)	Choline (mg)	Vit. B12 (µg)	Vit. C (mg)
Profiles for 'single staple' models[c]								
Maize flour, whole grain, white	0.0	0.20	0.07	0.33	17.50	21.6	0.00	0.0
Rice, white, long-grain	0.0	0.06	0.04	0.16	5.60	5.8	0.00	0.0
Starchy roots, tubers, plantains	11.5	0.08	0.03	0.21	16.69	14.6	0.00	7.7
Unhealthy beverages and foods								
SSB beverages, average	0.0	0.00	0.00	0.00	0.00	0.2	0.00	0.0
Sweet biscuit, average	1.3	0.16	0.04	0.07	8.30	8.1	0.02	0.1
Crisps and chips, average	7.7	0.15	0.07	0.44	9.67	16.0	0.00	7.2
Fortified products								
MNP – 1 g dose	400.0	0.50	0.50	0.50	150.00	0.0	0.90	30.0
SQ-LNS – 20 g dose	400.0	0.30	0.40	0.30	133.40	10.4	0.50	15.0
SCP – per 100 g	1040.0	0.20	1.40	1.00	110.00	51.0	2.00	90.0

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement; SSB = sugar-sweetened beverage.

[b] All values are per 100 grams, except as indicated for MNP and SQ-LNS.

[c] Nutrient values for grains are for raw/dry forms, after applying USDA retention adjustments for boiled, steamed maize flour and rice cooked with water. Nutrient values for roots/tubers/plantains are as shown in Table A6.2, for wet/cooked forms or raw forms with retention adjustments.

Table A6.7. Non-target nutrient profiles: Macronutrients and minerals[a, b]

	Protein (g)	Carbohydrate (g)	Fiber (g)	Magnesium (mg)	Phosphorus (mg)	Copper (mg)
Profiles for 'single staple' models[c]						
Maize flour, whole grain, white	6.9	76.9	7.3	93.0	272.0	0.23
Rice, white, long-grain	7.1	80.0	1.3	25.0	109.3	0.22
Starchy roots, tubers, plantains	1.5	25.8	1.9	21.1	34.9	0.13
Unhealthy beverages and foods						
SSB, average	0.0	13.2	0.0	0.5	4.5	0.01
Sweet biscuit, average	6.5	72.9	1.9	18.4	99.0	0.10
Crisps and chips, average	4.8	60.8	3.2	65.2	142.0	0.15
Fortified products						
MNP – 1 g dose	0.0	0.0	0.0	0.0	0.0	0.56
SQ-LNS – 20 g dose	2.6	5.3	0.3	40.0	196.4	0.34

SCP – per 100 g	16.0	63.8	2.9	111.7	280.0	0.35

[a] MNP = multiple micronutrient powder; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement; SSB = sugar-sweetened beverage.

[b] All values are per 100 grams, except as indicated for MNP and SQ-LNS.

[c] Nutrient values for grains are for raw/dry forms, after applying USDA retention adjustments for boiled, steamed maize flour and rice cooked with water. Nutrient values for roots/tubers/plantains are as shown in Table A6.2, for wet/cooked forms or raw forms with retention adjustments.

Table A6.8. Non-target nutrient profiles: Vitamins and fatty acids[a, b]

	Niacin (mg)	NE[c] (mg)	Vit. D (μg)	LA or 18:2[d] (g)	ALA or 18:3[d] (g)
Profiles for 'single staple' models[e]					
Maize flour, whole grain, white	1.71	2.53	0.00	1.71	0.05
Rice, white, long-grain	1.60	2.98	0.00	0.15	0.03
Starchy roots, tubers, plantains	0.94	1.38	0.00	0.03	0.01
Unhealthy beverages and foods					
SSB, average	0.00	0.00	0.00	0.00	0.00
Sweet biscuit, average	1.93	3.60	0.00	2.98	0.28
Crisps and chips, average	2.32	3.32	0.00	5.31	0.85
Fortified products					
MNP – 1 g dose	6.00	6.00	5.00	0.00	0.00
SQ-LNS – 20 g dose	4.00	5.76	5.00	4.46	0.58
SCP – per 100 g	8.00	11.00	11.00	5.25	0.59

[a] ALA = alpha-linolenic; LA = linoleic; MNP = multiple micronutrient powder; NE = niacin equivalents; SCP = Super Cereal Plus; SQ-LNS = small-quantity lipid-based nutrient supplement; SSB = sugar-sweetened beverage.

[b] All values are per 100 grams, except as indicated for MNP and SQ-LNS.

[c] We calculated NE as mg niacin + mg tryptophan/60. Data for tryptophan are missing for ~30% of items. We examined the impact of missing values and judged that the missing values did not bias means for niacin equivalents.

[d] Nutrient values for ALA and LA were available for slightly fewer than one-quarter of food items. We used these values when available but otherwise used values for undifferentiated 18:3 and 18:2 fatty acids, respectively.

[e] Nutrient values for grains are for raw/dry forms, after applying USDA retention adjustments for boiled, steamed maize flour and rice cooked with water. Nutrient values for roots/tubers/plantains are as shown in Table A6.2, for wet/cooked forms or raw forms with retention adjustments.

Annex 7 Further details of development of quantitative parameters

As detailed in Annex 4 Tables A4.1 and A4.2, we used available data sets, published papers, and reports to inform development of quantitative parameters for food groups and subgroups.[29] Selection of parameters was based primarily on our own analysis of data sets, but we augmented with other sources when appropriate.

We relied primarily on our own analyses because published papers and reports were highly heterogeneous in use of food groups and subgroups. However, for some limited uses, reports of prevalence of consumption and/or median gram amounts of certain items or subgroups was of relevance for our selection process, as described below.

As detailed in Section 2b.5, Optifood models food patterns on a weekly basis, but the modeling depends on the following mix of daily and weekly parameters:

- Median grams per day at the food subgroup level; referred to as 'daily servings'
- Maximum number of days in the week the food subgroup can be consumed
- Maximum number of daily servings per week, at the level of the broad food group

In this Annex, we provide a more detailed description of how these three parameters were specified. Methodological choices were guided by our objective: that is, to allow for generous yet realistic amounts of nutrient-dense food subgroups.

Median grams per day at the food subgroup level

We set quantity constraints for a maximum allowed daily serving based on observed median intakes. Results were available from data sets from 8 countries for infants 6-11.9 months of age, and from 14 countries for children 12-23.9 months of age. These results guided our selection of parameters but given that our data are not globally representative, we also employed judgment in setting final parameters, following this process:

1. We excluded food subgroup-level data from any data set with fewer than 20 consumers of the subgroup; this partially addressed the issue of outliers;[30]
2. We then selected from among the larger observed median grams per day (that is, 'larger' considering medians across all non-excluded countries);
3. Specifically, in most cases we took the average of the two highest country medians and set this as the daily serving in grams;
4. In case of high outliers, we took the either the second highest country median, or the median from among all medians in the top quartile of countries;
5. In the case of bakery products, we considered medians for whole grain and refined grains together and took the average of the top two medians and used for both groups. This was to avoid the model 'preferring' refined grain bread, which empirically was consumed in larger quantities.
6. We rounded to the nearest gram or nearest five grams, depending on the food subgroup;

[29] Data sets were excluded from the quantitative analysis when more than one data set was available for the same geographic area; in these cases, the data set with a broader age range, or one judged to be of higher quality, was selected.

[30] The exception to this was for liver, for infants 6-11.9 months of age, because there were no data sets with 20 or more consumers. For this age group, we examined median grams consumed if at least 10 infants consumed liver.

7. For several subgroups, we further modified the maximum based on comparison with the other age group; that is, in the case of 3 subgroups, to avoid lower gram constraints for 12-23 months compared to 6.11.9 months we used the higher constraint from the younger age group for both age groups (high-fat fruits; fresh/green peas and beans; liver);
8. For several subgroups, we considered additional information from the literature, to broaden the geographic scope.

As noted, information from papers and reports generally could not be used in the same way as our data sets,[31] due to differences in food groupings. However, if, for example, the median serving size reported for a single item exceeded the highest median we observed at the subgroup level in the data sets, these 'literature-based' medians were considered in adjusting the maximum. See **Box A7.1** for two examples.

Box A7.1 Examples of use of reported medians from the literature

White starchy roots, tubers and plantains: Infants 6.11.9 months of age

Starchy roots/tubers/plantains were consumed by ≥20 children in data sets from 8 countries, with median daily intakes ranging from 9-60 grams. The two highest medians were ~ 53 grams (Mexico) and ~60 grams (Kenya), yielding an average of ~56 grams.

However, Faber (2005)[a] reported that median intake of potato alone was 80 grams per day for this age group in her study in rural South Africa (Kwa-Zulu Natal).

We considered this higher median along with the other data available to us and chose to set the parameter at 60 grams per day.

Pork: Children 12-23 months of age

Pork was consumed by ≥20 children in data sets from 7 countries, with median daily intakes ranging from 15-27 grams, and the median of the top two values was 26 grams. However, our available data sets did not include representation for East or Southeast Asia, where pork is consumed more widely than in other regions.

As listed in Annex 4, we had access to unpublished reports from the SMILING Project Optifood analyses, including for Vietnam.[b] The median daily serving used in the Vietnam Optifood analysis, for several types of pork, was 35 grams for this age group. We chose to use this for our daily serving size for pork.

[a] Faber M. Complementary foods consumed by 6-12-month-old rural infants in South Africa are inadequate in micronutrients. Public Health Nutr. 2005 Jun;8(4):373-81. doi: 10.1079/phn2004685. PMID: 15975182.

[b] Le Bach Mai, Thi Tran Lua, Thanh Do Tran, Hong Dung Le, Huy Tue Ha, Watson Louise, Ferguson Elaine. SMILING PROJECT Country Report for Vietnam. Personal communication from Elaine Ferguson, 30 June 2021.

There were several exceptions to the general process described above. The first was in our selection of daily serving sizes for milk for breastfed IYC 6-11.9 months of age. For children 12-23.9 months of age, after consultation with WHO staff regarding the resulting quantities, we followed the processes above.

[31] The data set from Israel also had to be used in a different way because it only included data on weekly consumption frequencies of foods or food groups and no information on consumption quantities.

But for breastfed infants, following the process described above would have led to high daily maxima for milk intake, because high intakes (well over 200 grams) were observed in several countries. However, high intake of milk can displace breastfeeding. At the same time, adding milk powder or fluid milk to porridge is actively recommended in a number of settings to improve nutrient density of porridges.

After discussion with WHO staff, we set maximum daily serving sizes for milk at:

- Breastfed infants 6-8.9 months		60 grams
- Breastfed infants 9-11.9 months		120 grams

In the data sets we analyzed, median milk intakes for breastfed infants 6.11.9 months of age ranged from ~40 to ~240 grams, across data sets from 8 countries. The 'median among the medians' was 80 grams, so the values selected for the two age subgroups bracket that value.

The other two exceptions were due to an error, which was not discovered until after the report was drafted. Maximum grams per day for soy foods and added fats for children 12-23 months of age were lower than intended. We reran the analyses and confirmed that the error had no impact on nutrient gaps and only very minor impacts on food patterns. No key results or conclusions were affected.

Maximum number of days per week food subgroups can be consumed

The maximum number of days per week was estimated based on the percent of children consuming the food subgroup on the recall day(s), following the method of Skau et al. (2014). Ideally, this parameter would be based on food frequency data, but such data were not available to us. Optifood researchers have developed an estimation method based on (at least) a single day of intake data.

The estimation proceeds as follows:[32]

Denote by x the binary random variable which represents consumption of a given food subgroup on a day (x=1 if the food subgroup is consumed and 0 if not). The probability distribution of x is best described by a Bernoulli distribution with the parameter p defined as:

Probability (consumption=1) = p
Probability (consumption=0) = $1 - p$

Note that the probability p is the probability of a generic child in the population consuming the subgroup on a given day. This is equivalent to the percent of children consuming on that day under the following simplifying assumptions:

- The current day's consumption has no influence on any subsequent day's consumption (that is, independence);
- p is stationary (that is, does not change with time across the week).

The above relationships are defined per day, and the range of the maximum number of days of consumption per week is 0 to 7.

Next, define the probability distribution function of the maximum number of days of consumption in a week. Denote this variable by y. This is given by:

$$y = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7$$

where $x_1 \ldots x_7$ are the results of the Bernoulli trials on each day in one week, and y is a binomially distributed random variable with parameters $(7, p)$.

[32] We are grateful to Dr. Zaid Chalabi of University College London for his assistance in further elaborating the details of this method.

For each p (= prevalence of consumption) it is then possible to examine the distribution and identify the lowest number of days per week at or below which at least 95% of the distribution falls. This yields the following (**Table A7.1**), as in Skau et al. (2014).

Table A7.1 Relating prevalence of consumption to maximum days per week

Prevalence of consumption	Maximum number of days per week
0-5%	1
6-12%	2
13-22%	3
23-34%	4
35-47%	5
48-65%	6
66-100%	7

As the percent consuming each subgroup varied across countries, we selected the percent for each subgroup from the country where this percent was highest as the basis for estimating the maximum number of days per week. This was consistent with our aims and resulted in a generous total number of grams per week for each subgroup, reflective of settings where the food subgroup was widely consumed and accessible.

We considered the percent consuming in the available data sets as well as in several studies and reports. As described above for median intakes in grams, if – in one of the studies or reports – the percent consuming a single item exceeded the maximum percent for the food subgroup in the data sets we analyzed, this informed our selection.

For example, in the data sets available to us the highest percent of infants 6.11.9 months of age consuming high fat fruits was approximately 4%, for a maximum of 1 day per week. However, in Helen Keller International's ARCH 2 study in Indonesia, 9% of infants in this age group consumed avocado.[33] We took this as the maximum percent consuming, for a more generous maximum of 2 days per week. Similarly, we used information from other sources to inform a more liberal number of days per week for pork to be consumed.

Exception: for breakfast cereals, the method described above would have yielded different maximum numbers of days per week for whole-grain vs. refined grain cereals. We choose to allow the same maximum, set at the higher of the two derived as above.

See Table 10 in Section 2b.5 for the maximum frequencies for each food subgroup. In addition to modeling with these maxima, we also performed sensitivity analyses by allowing all food subgroups a maximum of 7 daily servings per week.

Maximum number of daily servings per week, at the level of the broad food group
At the level of broad food groups, Optifood does not use constraints expressed in grams, but rather expressed in the number of daily servings allowed, across all subgroups in the broad food group. Following the usual Optifood process, the food-group level constraints were developed as follows:

1. For each child, we counted the number of subgroups consumed within each main food group, then multiplied this count by 7 to estimate weekly frequencies, assuming:

[33] Unpublished data: Helen Keller International's Assessment and Research on Child Feeding (ARCH) Project. ARCH Project ((https://archnutrition.org/) data were analyzed and provided in tabulated format by Alissa Pries.

a. Food patterns (number of subgroups within each group) remain relatively static over 7 days for each individual; and

b. Overestimation errors are balanced by underestimation errors at the population level;

2. Next, we calculated percentiles for these weekly frequencies, including both consumers and non-consumers (children who had 0 subgroups within a main food group);
3. We examined the percentile distributions in each dataset, and selected a maximum based on the 90th percentiles of the distributions that included both consumers and non-consumers;
4. Specifically, we took the median from among the top quartile of these 90th percentile values.

As for food subgroup level frequency constraints, this approach is liberal in allowing a frequency reflective of the higher end of consumption frequency.[34]

Exception: For dairy foods for breastfed infants 6.11.9 months of age, in addition to selecting values for daily servings in grams differently, we also adjusted the maximum daily servings per week down to 14 (that is, daily servings of up to 2 of 3 dairy subgroups), which we considered to be ample for breastfed infants.

[34] Note that this approach yielded a maximum 'allowed' weekly energy intake from grains that exceeded estimated energy requirements for the lowest energy scenario (that is, for the smallest 6-8.9 month olds). However, as maximum allowed quantities of grains are generally not selected, for other reasons, we judged this did not affect the modeling and results.

Annex 8. Developing food patterns to approximate real-world situations

Using data from Bangladesh, Malawi and Mexico, we developed food patterns characterized as the percent of energy from food groups and subgroups, and then translated these into grams per subgroup. We needed to 'rescale' to estimate grams per subgroup because the observed energy intakes in each data set did not align with our fixed energy levels, which were the estimated energy requirements (EERs) used in the modeling (see Annex 1). In our scenarios, we assumed energy intakes would meet the EERs.

We also assumed a fixed percent of energy as breast milk for each age group, as in the modeling. Using fixed breast milk intakes and fixed EER, we defined the energy available for complementary foods and beverages (hereafter, 'CF'). We rescaled intakes such that patterns (percents of energy for food groups and subgroups) were as observed in the data sets, but the quantities (grams, kcals) differed to allow all kcals to sum to the EER.

For our optimization modeling, we used three energy levels for each age group in our initial modeling of best-case scenarios (low, middle, and high; see Annex 1 for details). For the scenarios described here, we selected one energy level for each country setting. We considered body weight data available in the data sets, and also the nutrition situation in each country. **Table A8.1** shows body weight by age group in the data sets, and **Table A8.2** shows data for anthropometric indicators at national level for the three countries.

Table A8.1. Mean body weight

	Bangladesh Breastfed	Malawi All[a]	Mexico All
6-8.9 mo	7.2	7.7	8.1
9-11.9 mo	7.8	8.4	8.9
12-15.9 mo		9.0	
12-23.9 mo	8.8		10.7

[a] In Malawi ~99% of IYC were breastfed.

Table A8.2. Prevalence of stunting, wasting and overweight[a]

	Bangladesh	**Malawi**	**Mexico**
Stunting (%)	30.2	37	12.1
	Very high	Very high	Medium
Wasting (%)	9.8	0.6	1.4
	Medium	Very low	Very low
Overweight (%)	2.1	4.7	6.3
	Very low	Low	Medium

[a] United Nations Children's Fund (UNICEF), World Health Organization, and International Bank for Reconstruction and Development/The World Bank. 2021. 'Levels and Trends in Child Malnutrition: Key Findings of the 2021 Edition of the Joint Child Malnutrition Estimates.' New York: United Nations Children's Fund. https://data.unicef.org/resources/jme-report-2021/.

For Bangladesh and Malawi, we selected the EERs based on low body weights. For Mexico, we selected the EERs based on average body weights.

Once EERs were selected, we calculated grams per food subgroup for each data set and age/feeding group in each setting, as follows:

1. Energy intake from excluded items was dropped from the total energy from CF (see Annex 3 for details of excluded items). Note that both breast milk and infant formula were excluded at this stage.
2. We further excluded food subgroups that were not consumed by at least 5% of the IYC in a given age group (6-11.9 months and 12-23.9 months).
3. We summed energy from all non-excluded food groups and subgroups = Total CF kcals.
4. We calculated the percent of energy for each food subgroup as:

   (Mean energy (kcals) for the food subgroup ÷ Total CF kcals from #3 above) * 100.
5. We calculated the percent of energy from the five broad food groups by summing subgroups in #4.
6. We back-calculated kcals for each subgroup as:

   (Available CF kcals * Percent of kcals from each subgroup from #4) ÷ 100.
7. We calculated grams per food subgroup as:

   (Kcals per subgroup from #6 * 100) ÷ Kcals per 100 g of the subgroup in the nutrient profile

These gram amounts were subsequently used to calculate the nutrients in the food patterns and the percent of NRV for each nutrient.

Note that the procedure above has the effect of allocating energy from excluded items across all other food subgroups proportionately, which may not be warranted. However, we had no basis for doing otherwise. The nature of the excluded items varied from country to country and somewhat across age groups within countries.

In Bangladesh, almost all excluded items were added sugars. In Malawi the most common excluded items were sugar (by far the most common), broth, and plain tea. In Mexico the most common excluded items (aside from salt and water) were garlic, sugar and soup broth. By apportioning the kcals from these items proportionately across the other food groups, food patterns were slightly improved, but remained impoverished in Bangladesh and Malawi with very high percents of energy from starchy staple foods. The Mexican food pattern is somewhat better.

Note that our data for food subgroup consumption were averaged across breastfed and non-breastfed IYC, implicitly assuming that patterns are similar in the two feeding groups, after excluding breast milk and formula. This was because in many settings, subgroups based on milk feeding would have been too small for analysis. However, it is quite possible that food patterns would differ.

Therefore, in most cases we restricted our scenarios to ones where this assumption was less major. In Bangladesh and Malawi, nearly all IYC were breastfed, so we created scenarios for breastfed IYC. In Mexico, feeding was more mixed during infancy. We nevertheless created a scenario for breastfed infants, in this case assuming that patterns would be similar across feeding groups, which may not be warranted. For 12-23.9 month old children in Mexico only 14% were breastfed, so we created a scenario for non-breastfed children only.

Though these limitations are important ones, we hope the scenarios will be useful as examples of broad patterns, with some basis in real-world settings.

Table A8.3 shows the percent of energy from each group and subgroup for each setting.

Table A8.3. Percent of energy from food groups and subgroups in three quasi-real-world scenarios[a]

	Bangladesh		Malawi		Mexico	
	6-11.9 mo	**12-23.9 mo**	**6-11.9 mo**	**12-15.9 mo**	**6-11.9 mo**	**12-23.9 mo**
Starchy staple foods	59.8	68.0	66.5	56.8	19.8	24.5
Whole grains		2.0	41.9	31.2		1.6
Refined grains	57.1	60.4	24.6	25.0	7.2	9.5
Whole grain breakfast cereals					1.4	1.1
Refined grain breakfast cereals						
Whole grain bakery products					6.9	9.1
Refined grain bakery products		2.4		0.5	0.9	1.8
Starchy roots, tubers, plantains	2.7	3.1			3.4	1.4
Fruits	0.0	0.0	0.0	0.7	9.1	7.5
Vitamin A-rich fruits				0.7	1.2	1.1
Berries						
Citrus					0.8	1.7
Vitamin C-rich fruits						
Bananas					2.9	3.2
High-fat fruits						
Other fruits					4.2	1.6
Vegetables	1.4	2.3	1.2	1.3	4.0	2.1
Dark green leafy vegetables		0.3	0.4	0.3		
Other brassicas	0.2	0.2			0.9	0.2
Vitamin A-rich orange vegetables					0.7	0.3
Peppers and tomatoes	0.1	0.1	0.7	0.9	0.7	0.6
Peas and beans (immature seeds/pods)	0.5	0.8				0.0
Other vegetables	0.6	0.9	0.1	0.1	1.8	1.0
Dairy	15.8	5.9	0.0	1.1	35.5	27.4
Milk	15.8	5.9		1.1	28.2	20.8
Yogurt					6.3	4.6
Cheese					1.0	2.0

	Bangladesh		Malawi		Mexico	
	6-11.9 mo	**12-23.9 mo**	**6-11.9 mo**	**12-15.9 mo**	**6-11.9 mo**	**12-23.9 mo**
Protein foods	4.9	5.4	12.0	12.7	11.0	12.4
Eggs	4.3	1.9		0.4	3.2	3.9
Legumes		1.5	2.9	3.6	2.6	2.5
Soy foods			1.9	0.9		
Nuts and seeds			6.5	4.0		
Beef, lamb, goat, game					2.1	1.5
Pork						
Poultry					3.1	4.5
Liver						
Small fish		0.5	0.6	3.4		
Large fish	0.7	1.6		0.5		
Added fats and oils	5.3	7.0	12.4	16.1	4.3	5.5
Solid fats and saturated oils					0.7	0.9
Other vegetable oils	5.3	7.0	12.4	16.1	3.6	4.6
Sentinel unhealthy items	12.7	11.4	8.0	11.2	16.3	20.7
Sugar-sweetened beverages				1.4	4.0	4.9
Sweet biscuits	12.7	8.9	4.0	5.7	9.8	12.1
Crisps/chips		2.5	3.9	4.2	2.5	3.6

[a] Blank cells indicate that the food subgroup was not consumed by at least 5% of the IYC.