**Paper 1: Global impact and costs of fortification**

*How does fortification impact micronutrient inadequacies and what does it cost to implement?*

**OBJECTIVES**

1. To estimate country- and population group-specific prevalences of inadequate micronutrient intakes accounting for LSFF programs as currently implemented (i.e., “current programs with current compliance”).
2. To estimate the potential impacts of improving existing LSFF programs or establishing new ones on the estimated prevalences of inadequate micronutrient intakes. This will be done by modelling the following scenarios:
3. Improved industry compliance with existing fortification standards (i.e., “current programs with existing standards and improved compliance”)
4. [other scenarios TBD – see table below]
5. To estimate the national and global cost of LSFF programs as currently implemented (i.e., “current programs with current compliance”) and the national and global cost of improving existing LSFF programs or establishing new programs (in accordance with the scenarios defined in Objective 2).

**Table 1**: Overview of scenarios modelled to estimate the prevalence of inadequate micronutrient intakes1 and potential impacts of improving food fortification programs

|  |  |  |  |
| --- | --- | --- | --- |
| **Scenario2** | **Fortification standards3** | **Compliance** | **Notes** |
| 1. Current programs, current compliance | As reported in GFDx | As reported in the GFDx (estimated if data were missing) | In countries with a fortification standard for one or more of the five foods4, this scenario reflects additional micronutrient intakes based on retaining the current standard for each food.  In countries with no fortification standard for a specific food, this scenario reflects no additional micronutrient intakes from that food. |
| 1. Current programs, improved compliance | As reported in GFDx | 90% | Same as scenario #1 |
| 1. Aligned standards, current compliance | Aligned to reflect current international fortification guidelines (estimated if no existing guideline) | As reported in the GFDx (estimated if data were missing) | In countries with a fortification standard for one or more of the five foods4, this scenario reflects additional micronutrient intakes based on aligning the standard to reflect current guidelines for each food (in terms of type and amount of micronutrient(s) to add).  In countries with no fortification standard for a specific food, this scenario reflects no additional micronutrient intakes from that food. |
| 1. Aligned standards, improved compliance | Aligned to reflect current international fortification guidelines (estimated if no existing guideline) | 90% | Same as scenario #3 |
| 1. New/Aligned standards, improved compliance | Aligned to reflect current international fortification guidelines (estimated if no existing guideline) | 90% | In all countries, this scenario reflects additional micronutrients intakes based on aligning the standard to reflect current guidelines for specific foods4 that deliver micronutrients for which the global prevalence of inadequate intakes without fortification was >X%5 |

1 Micronutrient assessed included: vitamin E, Riboflavin (B2), folate (B9), vitamin C, vitamin B6 (pyridoxine), vitamin A (RAE), vitamin B12 (cobalamin), thiamin (vitamin B1), niacin (vitamin B3), iodine, calcium, iron, zinc, selenium, and magnesium

3 Included both mandatory and voluntary standards

4 Fortified foods included in the analyses were salt, oil, rice, wheat flour, and/or maize flour.

5 Based on results from Passarelli et al (i.e., the baseline scenario before accounting for fortification). Micronutrients for which the global prevalence of inadequate intakes (without fortification) included: [add final list of micronutrients. Fortified foods that deliver those micronutrients and were included were: add final list of foods]

**METHODS**

**Subnational population groups**

34 subnational age-sex groups, i.e., males and females in 17 age groups: 0- to 80-yrs-old in 5-yr groups, plus an 80+ age group) for 185 countries (same groups and countries as in Passarelli et al.).

**Estimation of micronutrient intake inadequacy**

*Step 1: Estimation of micronutrient intake from diet (without fortification)*

* Apply method from Passarelli et al. that accounts for shape of a population’s micronutrient intake distribution, based on dietary intake from 31 countries to estimates of micronutrient intake from food from individual-level global dietary database (GDD)

*Step 2: Estimation of additional micronutrient intake from fortified foods for each fortification scenario*

* Calculation for each fortified food and micronutrient combination (e.g., salt-iodine, wheat flour-iron):
  + ***Average daily per capita availability of food vehicle x Micronutrient content in fortification standards x Proportion of food vehicle industrially processed x % Compliance with fortification standards***
    - Where multiple foods are fortified with the same micronutrient in a country, estimate the additional micronutrient intake for each fortified food-micronutrient combination separately and sum intakes by micronutrient
* For scenario 1, current programs with current compliance:
  + For all countries:
    - Average daily per capita availability of each food vehicle is taken from GFDx (i.e., *Daily food intake/availability (g/c/d)*), which is based on data from FAO Supply Utilization Accounts (for most foods) or other sources (for salt)
      * Adjustment: The energy intake is normalised to what we estimate is consumed in terms of total energy based on the energy required to sustain measured levels of body weight, height, and physical activity.
  + For countries with a current fortification program (i.e., they have mandatory or voluntary legislation status for the specific food vehicle according to GFDx (i.e., *Legislation status)*):
    - Micronutrient content in fortification standards is taken from GFDx (i.e., *Nutrient level in standard (mg/kg)*)
    - Proportion of food vehicle industrially processed is taken from GFDx (i.e., *Proportion industrially processed (%)*) or estimated if missing data [approach for missing data TBD once we see how much is missing]
    - % compliance with fortification standards is taken from GFDx (i.e., *Proportion fortified (%)*) or estimated if missing data [approach for missing data TBD once we see how much is missing]
  + For countries with no current fortification program for a specific food:
    - Additional micronutrient intakes from that food are set at zero
* For scenario 2, current programs with improved compliance:
  + For countries with a current fortification program (mandatory or voluntary):
    - Same as scenario #1 above but % compliance with fortification is set to 90% for all fortified food-micronutrient combinations
  + For countries with no current fortification program for a specific food:
    - Additional micronutrient intakes from that food are set at zero

Table 2. Data sources and relevant variables

|  |  |  |
| --- | --- | --- |
| **Source (excel file name)** | **Relevant variables** | **Notes** |
| Food Intake and Availability\_20240730 | Country, Food vehicle, Legislation Status, Data year, **Daily food intake/availability (g/c/d)** | * Use most recent year for which data are available for * An adjustment for overall energy supply to energy expenditure for different age-sex groups will need to be applied |
| Number of Food Vehicles with Standards\_20240729 | Country, Food vehicle, Legislation status, Nutrient, **Nutrient level in standard (mg/kg)** |  |
| Proportion of Industrially Processed Food Vehicle\_20240729 | Country, Food vehicle, Legislation status, Data year, **Proportion industrially processed (%)** | * Use most recent year for which data are available |
| Proportion of Fortified Food Vehicle\_20240730 | Country, Food vehicle, Legislation status, Data year, **Proportion fortified (%)** | * Use most recent year for which data are available |

* For scenario 3, aligned standards and current compliance:
  + For countries with a current fortification program (mandatory or voluntary):
    - Same as scenario #1 above but micronutrient content in fortification standards is taken from new excel file (Aligned\_standards\_scenarios\_20240830). The standard applied reflects the estimated average daily per capita availability of each food vehicle and the estimated extraction rate for wheat and maize flour.
      * Note: no guideline exists for rice and oil therefore need to determine approach micronutrient content in fortification standards
  + For countries with no current fortification program for a specific food:
    - Additional micronutrient intakes from that food are set at zero
* For scenario 4, aligned standards and improved compliance:
  + For countries with a current fortification program (mandatory or voluntary):
    - Same as scenario #3 above but % compliance with fortification is set to 90% for all fortified food-micronutrient combinations
  + For countries with no current fortification program for a specific food:
    - Additional micronutrient intakes from that food are set at zero
* For scenario 5, new/aligned standards and improved compliance:
  + For all countries:
    - First, determine which micronutrients are considered a global public health problem (e.g., based on global prevalence of inadequacy before fortification from Passarelli et al) – need to determine a cut off % to use to select micronutrients (see table below)
    - Second, select foods to fortify that can deliver the selected micronutrients (see table below)

|  |  |  |
| --- | --- | --- |
| **Micronutrient (global prevalence of inadequacy before fortification from Passarelli et al.)** | **Food micronutrient can be added to** | **What to apply in all countries** |
| Iodine (68%) | Salt | Salt with iodine as per aligned standard |
| Vitamin E (67%) | Oil | Oil with vitamin E as per aligned standard |
| Calcium (66%) | Wheat flour | Wheat flour with calcium as per aligned standard |
| Iron (65%) | Wheat flour, maize flour, rice | Could do all and/or apply separately |
| Vitamin B2/ Riboflavin (55%) | Wheat flour, maize flour | Could do all and/or apply separately |
| Folate (54%) | Wheat flour, maize flour, rice | Could do all and/or apply separately |
| Vitamin C (53%) | None | Not applicable |
| Vitamin B6/ Pyridoxine (51%) | Wheat flour, maize flour, rice | Could do all and/or apply separately |
| Vitamin A (48%) | Wheat flour, maize flour, oil | Already included in selected foods above |
| Zinc (46%) | Wheat flour, maize flour, rice | Already included in selected foods above |
| Vitamin B12 (39%) | Wheat flour, maize flour, rice | Already included in selected foods above |
| Selenium (38%) | None (only 1 country standard currently includes it for rice) | Not applicable |
| Magnesium (31%) | None | Not applicable |
| B1/Thiamin (30% | Wheat flour, maize flour, rice | Already included in selected foods above |
| B3/Niacin (22%) | Wheat flour, maize flour, rice | Already included in selected foods above |

* + - Then, same as scenario #1 above but:
      * micronutrient content in fortification standards is taken from new excel file (Aligned\_standards\_scenarios\_20240830). The standard applied reflects the estimated daily per capita availability of each food vehicle and the estimated extraction rate for wheat and maize flour.
      * % compliance with fortification is set to 90% for all fortified food-micronutrient combinations

*Step 3: Estimation of micronutrient intake inadequacy prevalence for each fortification scenario*

* Sum micronutrient intake from diet + micronutrient intake from fortified foods
* Then apply probability method to determine prevalence of intake inadequacy
* Then calculate number of people within each subnational group

**Estimation of mean probability of adequacy across all micronutrients**

* Estimate probability of adequacy (PA) for all 15 micronutrients (ranging from 0 to 1.0) (this is equivalent to the prevalence of adequacy)
* Then take the average of the PA across the 15 micronutrients to calculate the mean probability of adequacy (MPA) as a summary variable for micronutrient adequacy

**Sensitivity analyses**

[details to be added later]

**Estimation of costs of implementing the fortification scenarios**

For each country and scenario, we will develop a cost model to estimate annual economic costs of fortification from a societal perspective. Cost estimates will reflect the additional or incremental cost of fortification and exclude costs involved in the production and distribution of the food vehicle in the absence of fortification. For each country and scenario, costs will be estimated as follows:

*Step 1: Estimate premix costs*

Using a database of micronutrient compound activity levels and prices, estimate the premix cost per kg and per metric ton (MT) of the food vehicle, including, where relevant, estimates of international shipping, import duties, VAT, and local transport and storage. Multiply the premix cost per MT by the estimated annual fortified quantity of the food vehicle in the food system, calculated as:

* daily per capita availability of the food vehicle (g/c/d)\*proportion of the food vehicle industrially processed\*compliance with fortification standards\*population size, and converted to MT per year

Notes:

* Rice fortification will be assumed via hot extrusion with fortified rice kernels mixed with unfortified rice at a blending ratio of 1:100. The cost of fortified rice kernels will account for premix, other ingredients (broken rice flour, emulsifier), and manufacturing costs.

Table 3. Data sources and relevant variables for estimating premix costs

|  |  |  |
| --- | --- | --- |
| **Source (excel file name)** | **Relevant variables** | **Notes** |
| MAPS premix cost calculator | Micronutrient compound price ($/kg), micronutrient compound activity level |  |
| GAIN Master Annex - Duties Taxes | Customs duty (%), VAT (%) |  |
| Number of Food Vehicles with Standards\_20240729 | Country, Food vehicle, Legislation status, Nutrient, **Nutrient level in standard (mg/kg)** |  |
| Micronutrient Compound\_20240722 | Country, Food vehicle, Nutrient, **Compound** | * For some micronutrients (e.g., iodine, iron), the national standard allows for more than one compound. Where price information is not available for a specific compound, another allowable compound will be assumed. Where price information is available for more than one allowable compound, we will make an assumption about the most likely compound in a give context (e.g., potassium iodide in higher income settings and potassium iodate in lower income settings). |
| Proportion of Industrially Processed Food Vehicle\_20240729 | Country, Food vehicle, Legislation status, Data year, **Proportion industrially processed (%)** | * Use most recent year for which data are available |
| Proportion of Fortified Food Vehicle\_20240730 | Country, Food vehicle, Legislation status, Data year, **Proportion fortified (%)** | * Use most recent year for which data are available |
| Food Intake and Availability\_20240730 | Country, Food vehicle, Legislation Status, Data year, **Daily food intake/availability (g/c/d)** | * Use most recent year for which data are available |
| WPP2019\_POP\_F01\_1\_TOTAL\_POPULATION\_BOTH\_SEXES | Country, Year, **Total population both sexes combined** | * Source is World Population Prospects * Use population size estimate for 2024 |

*Step 2: Estimate industry-related costs*

Industry-related costs include annualized equipment costs, labor associated with fortification, quality assurance/quality control (QA/QC), and management/administration. For each relevant food vehicle, we will approximate the number of industrial-scale processing facilities in each country based on the estimated domestically processed fortifiable quantity of the food vehicle in the food system and an approximation of the processing capacity of an industrial-scale facility.

The domestically processed fortifiable quantity of the food vehicle in the food system will be calculated as:

* daily per capita availability of the food vehicle (g/c/d)\*proportion of the food vehicle industrially processed \*proportion of the food vehicle domestically produced\*population size, and converted to MT per year

The number of industrial-scale processing facilities will be calculated as the domestically processed fortifiable quantity of the food vehicle in the food system divided by the assumed processing capacity of an industrial-scale facility (see Table 2 in https://www.advancingnutrition.org/resources/usaid-large-scale-food-fortification-programming-guide-supporting-food-fortification).

For each industrial-scale processing facility, annualized equipment cost will be estimated based on food-vehicle-specific data collected in the context of the MAPS project. Fortification and QA/QC labor costs will be based on assuming 1 FTE with salary based on a percentage of GDP per employed person. Supply costs for QA/QC will be based on data collected in the context of the MAPS project. Management/administration will be estimated as a percentage of recurring industry-related costs.

Table 4. Data sources and relevant variables for estimating industry-related costs

|  |  |  |
| --- | --- | --- |
| **Source (excel file name)** | **Relevant variables** | **Notes** |
| Proportion of Industrially Processed Food Vehicle\_20240729 | Country, Food vehicle, Legislation status, Data year, **Proportion industrially processed (%)** | * Use most recent year for which data are available |
| Food Intake and Availability\_20240730 | Country, Food vehicle, Legislation Status, Data year, **Daily food intake/availability (g/c/d)** | * Use most recent year for which data are available |
| WPP2019\_POP\_F01\_1\_TOTAL\_POPULATION\_BOTH\_SEXES | Country, Year, **Total population both sexes combined** | * Use population size estimate for 2024 |
| FAOSTAT\_data\_en\_8-5-2024 | Country, Year, Item, **import quantity, domestic supply quantity** | * The source is FAOSTAT * Use most recent year for which data are available |
| https://www.advancingnutrition.org/resources/usaid-large-scale-food-fortification-programming-guide-supporting-food-fortification | **MT/year low-income country, MT/y high income country** | * Figures in MT/year from Table 2 will be used to approximate the processing capacity of an industrial facility |
| API\_SL.GDP.PCAP.EM.KD\_DS2\_en\_excel\_v2\_2431503 | Country, **GDP per person employed** | * The source is the World Bank * Use most recent year for which data are available |

*Step 3: Estimate government-related costs*

For existing LSFF programs, government-related costs include annualized equipment costs, industry monitoring, import monitoring, commercial/market monitoring, social marketing, training, and management/administration. For new LSFF programs, government-related costs also include annualized planning and launching costs (e.g., industry assessment, development of standards, development of monitoring and evaluation plan, training).

Annualized equipment costs (for monitoring activities) and monitoring supply costs will be estimated based on food-vehicle-specific data collected in the context of the MAPS project. All other monitoring costs (primarily labor) will be roughly estimated based on the data collected in the context of the MAPS project, scaled by the quantity of the fortifiable food vehicle in the food system and GPD per person employed. Social marketing and training costs will be roughly estimates based on data collected in the context of the MAPS project and scaled by GDP per person employed. Management/administration will be estimated as a percentage of recurring government-related costs.

*Step 4: Summarize costs*

For each scenario, costs will be summarized as follows:

**Primary estimates:**

* Global annual average cost across all food vehicles
* Global annual average cost per person across all food vehicles
* Global annual average cost by food vehicle (salt, oil, rice, wheat flour, and maize flour)
* Global annual average cost per person by food vehicle (salt, oil, rice, wheat flour, and maize flour)

**Supplementary estimates:**

* National annual average cost across all food vehicles
* National annual average cost per person across all food vehicles
* National annual average cost by food vehicle (salt, oil, rice, wheat flour, and maize flour – where relevant)
* National annual average cost per person by food vehicle (salt, oil, rice, wheat flour, and maize flour – where relevant)

For improved compliance scenario, incremental costs will be summarized as follows:

**Primary estimates:**

* Global annual average incremental cost to improve compliance and expand programs across all food vehicles
* Global annual average incremental cost per person to improve compliance and expand programs across all food vehicles
* Global annual average incremental cost to improve compliance and expand programs by food vehicle (salt, oil, rice, wheat flour, and maize flour)
* Global annual average cost per person to improve compliance and expand programs by food vehicle (salt, oil, rice, wheat flour, and maize flour)

**Supplementary estimates:**

* National annual average incremental cost to improve compliance and expand programs across all food vehicles
* National annual average incremental cost to improve compliance and expand programs per person across all food vehicles
* National annual average incremental cost to improve compliance and expand programs by food vehicle (salt, oil, rice, wheat flour, and maize flour – where relevant)
* National annual average incremental cost to improve compliance and expand programs per person by food vehicle (salt, oil, rice, wheat flour, and maize flour – where relevant)