Recommendations for improving Guatemala's food fortification program based on household income and expenditure survey (HIES) data

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Abstract

Background. *Fortification offers great potential for reducing the enormous disease burden of micronutrient deficiencies. The lack of information on food consumption patterns has been a major impediment to the development of fortification programs. In some countries, the absence of this information has been an obstacle to the introduction of fortification. In countries that have fortification, governments are increasingly being challenged to provide evidence that programs are well designed and effective.*

Objective. *To examine the usefulness of household income and expenditure surveys (HIES) as a means for addressing this information gap and making fortification programs more evidence-based and more accountable.*

Methods. *Data from Guatemala's 2005/6 Living Standards Measurement Survey are used to develop a measure of "apparent food consumption." The measure is used to assess Guatemala's fortification program by analyzing the coverage and the additional micronutrient intake attributable to different food vehicles, combinations of food vehicles, and fortification formulations.*

Results. *There are three key findings. The impact of the wheat flour fortification program is considerably greater than had previously been estimated; the level at which sugar is currently fortified with vitamin A may be excessive and should be reviewed; and fortifying semolina flour (used to make pasta) would extend the benefits of wheat flour fortification to 60,000 households that currently do not benefit from it and would increase the amount of fortified food consumed by 68% of the population. Beneficiaries would include 63% of the extreme poor, and the greatest benefits would go to those wheat flour consumers who currently benefit the least from consuming fortified wheat flour products.*

Conclusions. *HIES data should be used more routinely as a tool in the designing, monitoring, and assessing of fortification programs.*

Key words: Food policy, fortification, household income and expenditure surveys, household surveys, micronutrients, nutrition

Introduction

Globally, more than 53 million disability-adjusted life-years and 1.5 million deaths of children under 5 years of age are attributable to deficiencies of vitamin A, iron, iodine, and zinc [1].Micronutrient deficiencies are due primarily to inadequate dietary intake. The World Health Organization (WHO) and the United Nations Food and Agriculture Organization (FAO) have adopted four main strategies for improving dietary intakes: food fortification, supplementation, nutrition education, and disease control measures [2]. Fortification—the addition of micronutrients to a processed food to improve the food's nutritional quality—is often regarded as the most attractive of these four strategies due to a combination of factors: it piggy-backs on an existing market, with existing distribution channels; it can improve people's micronutrient status without their having to choose to "participate" in the program, without their having to change their food behaviors, and without the need to educate them; it can have an impact in the short run; it is generally regarded as cost-effective relative to other three strategies; and it is thought to be more sustainable than a supplementation program, which is more subject to annual budget allocation competition.

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Despite these appealing characteristics and the fact that there is considerable experience in high-income countries implementing fortification programs, progress in middle- and lower-income countries has been slow—with the notable exception of salt iodization. This has been due to a number of factors, including inadequate understanding of the significance of micronutrient deficiencies; industry concerns about consumer acceptance, costs, and competitive impacts; the distinct and largely nontraditional types of activities that are required by governments to plan, initiate, monitor, and maintain a mass fortification program; and inadequate information about food consumption patterns.

This paper addresses the last of these obstacles, the food consumption information gap. Information about food consumption is essential for addressing the most fundamental fortification program design issues: the identification of which foods to fortify, with which micronutrients, and at what levels in order to reach and have the largest possible impact on the nutritional status of persons who suffer micronutrient deficiencies, and doing so without putting other consumers of the food at risk of consuming excess amounts.

Nutritionists maintain that the gold standard for food consumption information is 24-hour recall food consumption data from nationally representative household surveys. Few countries have conducted these surveys, and in many cases the absence of these data has discouraged fortification programs from ever being started. Other countries that do not have these surveys—Guatemala, for example—have designed programs with second-best data, such as FAO Food Balance Sheet and/or food industry sales data, often supplemented with expert opinions of food company officials or food industry analysts. These sources, however, have a number of weaknesses, the most important of which is that they are distribution-free, national totals and national per capita averages, rather than individual- or household-level data [3].

Guatemala has been a pioneer country in the fortification of staples. In 1975, it became the first country in the world to fortify sugar with vitamin A. The collaborative spirit of the food industry has been an important factor in the progress that has been made in fortification in Guatemala. While the food industry in general has remained committed to fortification, it has also become more demanding, asking for more evidence with which to inform program decisions, such as: How many people are reached by the program? Which foods might have better coverage? Which micronutrients should be included in fortification formulations? At what levels should they be added? Increasingly they are also asking about the impact of fortification on micronutrient intake and nutrition status.

In short, there is growing demand for a more rational, evidence-based food fortification policy in Guatemala—as there is in a rapidly growing number of countries throughout the world—and addressing that demand requires more information than is available from national-level data. It requires information about the food consumption patterns within the population, across households and/or individuals. In the absence of costly and difficult-to-implement 24-hour recall food consumption surveys, an alternative source of data that can provide information on variations in household food-related behavior is the household income and expenditure survey (HIES).* HIES provide data on food purchases, which with a modicum of assumptions can be used to proxy food consumption, referred to as "apparent food consumption."

This paper presents a case study of this approach using Guatemala's 2005/06 Living Standards Measurement Survey (LSMS)—generally referred to by its Spanish language name and acronym, Encuesta de Condiciones de Vida (ENCOVI)—to assess Guatemala's fortification policy. This is not the first time this type of survey has been used for this purpose in Guatemala. Imhoff-Kunsch et al. [4] analyzed the 2000 ENCOVI to assess the potential impact of wheat flour fortification. That study served as a point of departure for the analysis presented here. The current study introduces some important modifications. First, it analyzes a database that is more recent. Second, it incorporates three additional wheat flour-based foods (for a total of seven) in analyzing the impact of wheat flour fortification. Third, it expands the scope of inquiry, examining—in addition to the impact of wheat flour, which is currently mandated to be fortified—the potential impact of modifying the law to incorporate semolina flour, and it also analyzes the impact of vitamin A–fortified sugar. Fourth, and most importantly, this study adopts a different, more appropriate, two-pronged approach to estimating the impact of fortification.

The approach of Imhoff-Kunsch et al. [4] is based on Guatemalans' unconditional consumption levels, i.e., the consumption levels of the entire population, regardless of whether or not households or individuals consume any of the fortification food vehicle. In contrast, the approach adopted here posits the need for impact assessments to be considered two-part undertakings. The first part identifies those households that consume none of the food vehicle and assumes that these households are not impacted by the fortification program. The second part assumes that the estimated

* See Fiedler et al. [3] for a general discussion of the availability, common characteristics, and strengths and weaknesses of HIES as a tool in designing fortification programs. We use the label "HIES" loosely here to refer to any of the several HIES, ENCOVI, or similar types of regularly conducted national household surveys that collect information on households' expenditures on foods and other items.

impact of the program is limited to only those households that consume some of the food vehicle, and it is therefore based on the consumption levels of only this portion of the population; i.e., it should be based on conditional consumption levels (the consumption levels of all households/individuals, conditioned upon their consumption being greater than zero). As will be discussed in the final section of the paper, because the unconditional levels of consumption are less than the conditional levels of consumption, this difference in approach can have important implications: the use of unconditional rather than conditional consumption levels will result in underestimating the impact of a fortification program.

The paper proceeds as follows. The following section discusses nutritional status and the need for fortifying foods in Guatemala. The next two sections after that briefly describe Guatemala's fortification program and the database and methods. Two further sections discuss the additional intake of micronutrients attributable to fortified and fortifiable foods. The final two sections assess Guatemala's current fortification formulations in light of apparent food consumption data and state the conclusions of the study.

The nutrition status of Guatemalans

The nutrition status of Guatemalans has long been among the lowest of any country in the Western Hemisphere. Moreover, trends in different measures are mixed. Guatemala has one of the world's highest rates of stunting among children under 5 years of age. In 1999, the prevalence of stunting was 46%. In 2002, it was 49%, indicating that it was creeping upward at a rate of 1% per annum [5]. In contrast, there has been remarkable progress in reducing anemia among women. The prevalence of anemia fell by 60% between 1995 and 2002, going from 35% to 20% among non-pregnant women and 22% among pregnant women. No doubt, this trend is encouraging. At the same, however, according to WHO standards, anemia remains a "moderate" public health problem among women. Furthermore, among under-five children, the most recent national data estimate prevalence at 40%, making it a "severe" public health problem [2]. Anemia, therefore, should be a priority public health intervention.

The latest data on vitamin A deficiency in Guatemala come from a 1995 survey that found 16% of children 6 to 59 months old were deficient [6]. According to WHO, if the prevalence rate of vitamin A deficiency is equal to or greater than 10%, it constitutes a public health problem. Thus, despite the fact that at the time of that survey Guatemalan sugar had been fortified with vitamin A for most of the preceding 20 years —which presumably contributed to lowering the rate of vitamin A deficiency from what it would otherwise have been—vitamin A deficiency remains a public health problem.

As in most countries, Guatemala has no national data on the prevalence of zinc deficiency. The International Zinc Consultative Group (IZiNCG) has recommended that in the absence of direct measures of zinc deficiency, the prevalence of stunting or the prevalence of iron-deficiency anemia provides "suggestive evidence for the risk of zinc deficiency" [7]. Using either of these proxy measures suggests that young children in Guatemala are at high risk for zinc deficiency.

The most recent data on iodine deficiency come from a national survey conducted by the Guatemalan Ministry of Public Health and Public Assistance [6]. It found that the median urinary iodine content among school-aged children and women was 222 μg/L. According to WHO guidelines, this means that iodine deficiency is no longer a public health problem in Guatemala [8]. More recently, a 2002 subnational survey conducted in areas where iodine deficiency was suspected found the prevalence of iodine deficiency to be 14% [9]. It may be concluded that iodine deficiency is at most a mild public health problem in Guatemala.

Given the current level of knowledge, and as gauged by the proportion of the population affected and the severity of the deficiency, anemia should be regarded as Guatemala's most important micronutrient deficiency.

Fortification programs

Fortification programs have a long but discontinuous history in Guatemala. The first Guatemalan food fortification program began in 1954 with the passage of the Regulation of Fortification of Salt with Iodine. In 1975, Guatemala began fortifying sugar with vitamin A in response to the recommendation made by the Survey of Nutrition in Central America and Panama, which had found vitamin A deficiency to be a public health problem. Four years later, in 1979, all fortification efforts were terminated by order of the Government of Guatemala. The program was reinitiated in 1988 and has continued since then without interruption [10].

More recently, since the mid-1990s, there has been renewed interest in fortification in Guatemala and throughout Central America. In the mid-1990s, the Guatemalan fortified foods regulatory system was further elaborated and strengthened, and in 2002 the fortification of wheat flour—which industry had already voluntarily fortified at restorative levels—became mandatory, with revised and standardized regulations throughout Central America. For Guatemala, harmonization resulted in two important advances: increase in the level of folic acid fortification from 0.35 to 1.8 mg/kg, and a change in the iron compound from electrolytic iron to the more bioavailable ferrous fumarate.*

The 2005/2006 Living Conditions Survey

The 2005/2006 Living Conditions Survey (Encuesta de Condiciones de Vida, ENCOVI) was conducted by the Instituto Nacional de Estadísticas (INE). It was a national, multistage, proportional-to-population size (PPS), cluster sample-based survey. The sample consisted of 13,686 households composed of 68,739 individuals. The results reported here are the sample data "blown up" by the expansion factors (corrected for nonresponses) to enable more direct discussion of inferences about the entire Guatemalan population of 2,653,000 households and 12,987,829 persons.

The critical variable: Purchases of fortified and fortifiable foods

The 2005/2006 ENCOVI asked respondents about their household purchases of 116 different types of food. The general form of the key questions of interest in this analysis were:

» In the last 12 months, did you or some other member of your household purchase (……) to consume at home?
» In the last 12 months, during how months did you purchase (……)?
» How much money do you spend normally spend in a month on the purchase of (……)?
» In the last 15 days, what quantity of (……) did you purchase and how much money did you spend on it in total?

where (……) identifies the specific food from the list of 116 food items that was asked about. Each of the 116 food items was asked about individually.

The questionnaire also asked whether any of these 116 foods had been obtained by the household through home production or other means by which they did not have to pay. Several follow-up questions were then asked about those items for which the household responded affirmatively:

» In the last 12 months, during how months did you obtain (……) without having to pay for it?
» In the last 15 days, what quantity of (……) did you obtain without having to pay?
» Where did you usually obtain (……)?
1 = Own production
2 = Gift or donation
3 = As payment in kind
4 = Barter/in-kind trade

This set of questions about food obtained by other than purchase provides important information for a comprehensive understanding of food consumption and food security, but it is not part of this analysis.** The focus here is exclusively on food that is purchased, because it is more likely to be processed in formal, industrial settings, which is regarded as a prerequisite to its being fortifiable. Food that is home produced, and to a lesser extent that which is traded in kind or gifted, is much less likely than purchased foods to have been processed in modern plants and therefore is not included in this analysis.

For a number of reasons (to be discussed shortly), the quantity of food consumed may vary from the quantity of food purchased. It is important, therefore, to recognize that the food quantities discussed here are most precisely described as measuring not food consumption but "apparent food consumption." The aim of this study is the development of estimates of the coverage and impact of currently fortified foods and several potentially fortifiable foods. Impact will be measured as the apparent additional intake of micronutrients due to the apparent consumption of fortified foods. In order to take into account variations in the size, composition, and nutritional requirements of households in estimating the additional micronutrient intakes, the number of Female Adult Consumption Equivalent (FACE) units in the household was computed using the FAO methodology (presented in the **annex**). The quantities of food that households reported purchasing in the 15-day period prior to being interviewed were divided by the number of FACE units in the household, and that result was divided by 15 to yield estimates of the average daily apparent food consumption per FACE unit.

The analysis focuses on 19 of the 116 food items in the ENCOVI. These 19 foods (shown in **fig. 1**) were chosen either because they are (or contain) foods that are currently legally mandated to be fortified, or because they are viewed as potentially "fortifiable" based on experience in other countries, technical considerations, or on the recommendations or views of food or nutrition experts interviewed during the course of this study.

Limitations of the methodology

As already noted, the analysis is based on 15-day recall of household food purchases. Data collected over a longer period of time would provide a more precise characterization of household purchasing behavior

* Guamuch M. Wheat flour fortification: A simple program with a regional approach. Presentation at the A2Z USAID Nutrition Project Food Fortification Session, Micronutrient Forum, Istanbul, Turkey, 19 April 2007.

** Repeated attempts to obtain information about the fortification status of foods distributed in other government- or nongovernmental organization-supported programs were unsuccessful.

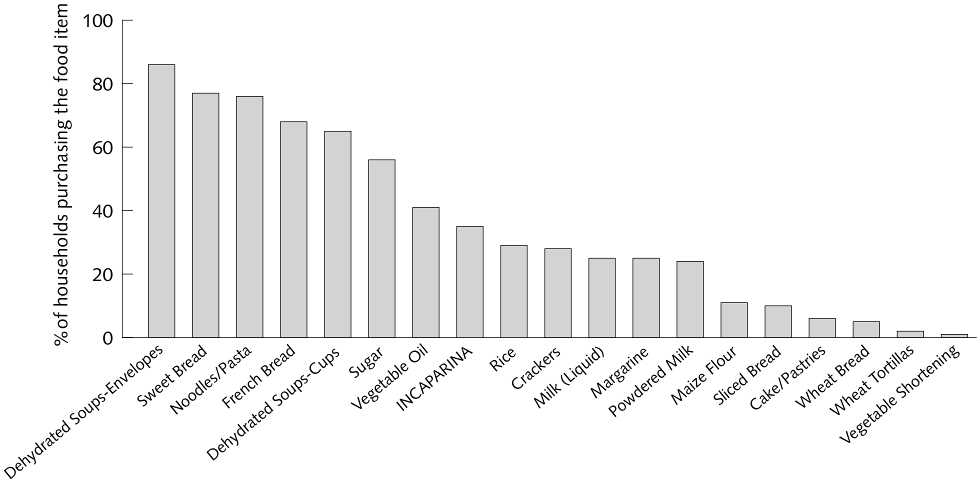

FIG. 1. Percentage of households purchasing specific food items in the last 15 days, Guatemala 2006

but would also be subject to greater recall errors. The 15-day recall period is thus a compromise between these two considerations. The 15-day recall period question was used as a screen to determine who was and who was not asked about the quantities of food purchased. Those households that purchased a particular food item in the past year, but did not purchase it in the past 15 days, were not asked about the quantities they purchased of the item. Thus, we do not know how much these households may have consumed in the past 15 days from preexisting purchased food supplies. This is a limitation of the methodology of the study. The implication is that the study underestimates the coverage of fortified foods and the potential coverage of fortifiable foods.

Another and related limitation of the study has to do with the estimation of household consumption from the quantity of a food item that a household purchases in the previous 15 days. It is implicitly assumed that none of the food is wasted, none of it spoils, and none of it is given away or used for other than human consumption. These assumptions result in the overestimation of household consumption.

A third limitation of the study stems from using household level data to estimate individual consumption levels. The method adopted divides total household food purchase in the previous 15 days by the household's total number of FACE units, and assigns to each individual a share equal to their FACE-equivalent share of total household consumption. This implicitly assumes that the distribution of food within the household is in direct proportion to biologic need (as captured by the FACE units), which may or may not be the case. This is the best-case scenario for intrahousehold food distribution and, as such, probably results in some degree of overestimation of the food received by some members of the household. To the extent that it does so, it undermines the validity of equating the level of household coverage of fortified foods with the level of individual coverage, and overestimates the additional intake of micronutrients attributable to the consumption of fortified foods.

A fourth limitation of the methodology is that the ENCOVI does not capture food that is purchased for consumption outside the home. This results in underestimation of the consumption of food and the intake of micronutrients, as well as the coverage of, and the additional micronutrient intake attributable to, fortified foods. To our knowledge, there have not been any studies that have quantified the importance of foods purchased for consumption outside the house or of the quantities of foods consumed outside the household in Guatemala or any other Latin American country, which might provide an indication of the importance of this limitation of the study. A recent study of Kenyan schoolchildren (6 to 16 years old), however, found that 13% and 19% of daily energy intake in the food shortage and harvest seasons, respectively, were contributed by foods consumed outside the home [11], suggesting this is an important source of underreporting of food consumption, and by implication of micronutrient intake. It is likely that in Guatemala—which has a per capita gross domestic product 3.5 times greater than that of Kenya—the importance of food purchased for consumption outside the home is even greater.

A fifth limitation is that not all of the food that is purchased will be processed in modern industrial plants where it will be more available for being fortified. Although the proportion of food purchased in supermarkets in Guatemala is estimated to have more than doubled between 2001 and 2008, only about half of all food purchases in the country in 2008 were made in supermarkets. The other half were made in small food shops and traditional wet markets, where food is more likely to be sold by producers (and/or intermediaries) directly to consumers, without being processed in modern plants, and thus is less likely to be fortifiable [12].

With some of these data shortcomings resulting in underestimation of consumption and others resulting in overestimation, it is not possible to quantify their net effect. It would seem, however, that taken together they would underestimate food purchases and apparent consumption.

Examining consumption patterns of 19 foods

The percentage of households purchasing 19 fortified or fortifiable foods

A rule of thumb used by food fortification experts is that for a fortification program to be regarded as a public health intervention, it must have coverage of at least 30% of the population, i.e., 30% of the population must consume the food to be fortified.* As may be seen in **figure 1**, only 8 of the 19 foods analyzed here pass this test. Of those eight, sugar is mandated to be fortified; INCAPARINA is a voluntarily fortified product; sweet bread, crackers, and French bread all contain wheat flour, which is mandated to be fortified; margarine and vegetable oil are occasionally voluntarily fortified; dehydrated soups in envelopes or cups are usually voluntarily fortified; and some brands of margarine and liquid milk are fortified.

The amount of food purchased in the previous 15 days

Food quantities were reported using a variety of measures and required standardizing. For 13 of the 19 food items, respondents were asked to report the quantity of the food they purchased in terms of its weight. The responses were in grams, kilograms, ounces, or pounds. These measures were converted to grams. In the case of liquid milk and vegetable oil, reported quantities were converted into milliliters. Purchases of sweet bread, French bread, wheat tortillas, and cakes or pastries were reported in "units" or "pieces," which were transformed into grams using INE's standardized set of weights.**

The figures reported in **table 1** for liquid milk and vegetable oil are in milliliters per FACE unit per day, and the other items are reported purchases (apparent consumption) in grams per FACE unit per day. The **annex** presents the algorithms used to translate the age and sex of household members into these standardized consumption units to enable taking into account different nutritional needs of households.

For each household, the standardized quantity of the food purchased in the previous 15 days was divided by the number of FACE units within the household and then divided by 15 to yield an average daily consumption level. **Table 1** presents the mean, the median, and the 5th, 25th, 75th, and 95th percentiles of the size distribution of purchases per household per day for all households purchasing some of each item.

Quantifying the coverage and impact of currently fortified foods in Guatemala

Measuring the wheat flour content of foods

In order to be able to estimate the additional intake of the micronutrients due to wheat flour fortification, it is necessary to combine all of the wheat flour-based products into a single composite. In constructing this measure, it is necessary to know the amount of each of the foods that is produced using the fortified wheat flour, and the amount of fortified wheat flour that is contained in each of the food items and the level of fortification.

In addition to fortified wheat flour (which is purchased as a final consumer good), there are 6 other food items among the 19 in this study that contain significant amounts of wheat flour. These foods, with the percentage of their total weight that is constituted by wheat flour in parentheses, are sweet bread (65%), French bread (60%), sliced bread (60%), crackers (90%), cakes and pastries (45%), and wheat tortillas (85%).

Multiplying these percentages by the number of grams of the respective food purchases per household and summing the totals for the seven foods for each household yields the household's estimated fortified flour equivalent consumption composite measure.*** The top portion of **table 2** contains the conditional descriptive statistics for household purchases per FACE unit per day of the wheat flour equivalents of each of these seven foods and the composite measure based on them, which is labeled Fortified Wheat Flour Equivalent (FWFE) definition 1. These totals were then converted into metric tons of wheat flour per day, and

* In contrast to being motivated primarily by public health concerns, fortification might alternatively be motivated by goals such as the promotion of Good Manufacturing Practices (GMPs).

** The INE weights are sweet bread, 25 g; French bread, 21 g; a portion or piece of cake, 28 g; and a wheat tortilla, 37 g.

*** It is important to recognize that the composite measure of total fortified flour equivalent is not derived by simply adding the mean, median, or some other descriptive statistic of the entire fortified wheat flour-consuming population's individual FWFE foods across households. Instead, it consists of summing the FWFE quantities within each household. These approaches result in markedly different estimates: the mean and median of the FWFE composite definition 1 are 87.0 and 106.2, respectively, while the sum of the composite's seven individual component foods' means and medians calculated over all fortified wheat flour-consuming households yields 229.7 and 150.2, respectively.

TABLE 1. Household purchases of selected foods in the past 15 days includes only those households purchasing some of the food item (in milliliters or grams/female adult consumption equivalent/day)

Indicator	Sweet bread	French bread	Sliced bread	Crackers	Cake/pastries	Wheat tortillas
Households that purchased						
Number	2,273,832.2	1,716,948.3	258,213.6	770,350.6	158,070.0	54,240.0
Percent	86%	65%	10%	29%	6%	2%
Quantity purchased						
Mean	76.0	77.6	35.4	12.3	9.5	40.1
Percentiles						
5	5.8	5.2	6.9	1.5	1.0	2.6
25	18.6	21.6	14.7	3.9	2.5	7.0
50	53.5	56.3	23.4	7.9	4.8	14.5
75	107.6	107.3	42.0	14.7	10.0	27.5
95	213.3	229.5	102.3	36.4	35.2	174.8
Indicator	Sugar	Maize flour	Wheat flour	Rice	Noodles/ pasta	Dehydrated soup in envelopes
Households that purchased						
Number	2,036,206.0	288,200.5	121,981.2	2,004,282.9	1,809,996.9	1,097,320.4
Percent	77%	11%	5%	76%	68%	41%
Quantity purchased						
Mean	132.5	107.6	33.5	50.3	32.7	6.1
Percentiles						
5	37.2	11.4	5.9	12.6	7.5	1.2
25	74.9	23.9	13.1	25.3	15.4	2.6
50	112.0	47.9	23.5	39.5	25.1	4.5
75	165.0	109.3	41.4	59.9	41.4	7.5
95	287.3	455.2	92.9	123.3	82.8	15.9
Indicator	Dehydrated soup in a cup	Powdered milk	Milk (liquid)	Vegetable oil	Vegetable shortening	Margarine
Households that purchased						
Number	731,753.7	641,919.7	650,096.4	1,476,476.9	15,131.0	662,243.9
Percent	28%	24%	25%	56%	1%	25%
Quantity purchased						
Mean	9.5	32.4	155.3	31.6	17.8	13.9
Percentiles						
5	1.8	4.6	18.2	7.9	6.2	2.4
25	4.1	10.8	41.4	15.7	9.4	6.5
50	6.8	21.1	82.0	24.8	12.0	11.1
75	11.5	41.7	181.9	39.0	23.9	16.9
95	26.3	95.0	545.8	79.2	45.9	35.2

their relative contributions to total FWFEs purchased throughout the country are shown in **figure 2**.

The FWFE composite allows us to measure the coverage of the Guatemalan wheat flour fortification program. Calculating the number of households that consume some fortified wheat flour is more complicated than simply summing the number of households that purchase each of the seven food items containing fortified wheat flour. This approach is flawed, because many households eat more than one of the seven items and therefore would be counted more than once. In fact, they could be counted up to seven times, depending upon how many of the seven fortified wheat flour-containing foods they purchase. Summing the coverage of each of item would result in counting many households more than once, and the end result would be nonsensical: the number of households that would be estimated would exceed the total number of households. Analysis of the Guatemalan households reveals that the mean number of fortified wheat flour products purchased by a household in the previous 15 days is 2.02 and the median is 2.00; applying this

TABLE 2. Apparent EAR for women 15–49 years old for micronutrients obtained from foritfied wheat flour (includes only households purchasing some of the selected food item)

Micronutrient type/household apparent consumption level	Sweet bread	French bread	Sliced bread	Crackers	Cakes	Wheat tortilla	Wheat flour	All wheat flour products (FWFE definition #1)
Households purchasing								
Number	2,273,832	1,716,948	258,214	770,351	158,070	54,240	121,981	2,445,630
Percent	86%	65%	10%	29%	6%	2%	5%	92%
Amount of FWFEs purchased								
Mean	49.4	46.6	21.3	11.1	4.3	34.1	33.5	87.0
5th percentile	3.8	3.1	4.2	1.4	0.4	2.2	5.9	5.1
25th percentile	12.1	13.0	8.8	3.5	1.1	6.0	13.1	20.9
50th percentile	34.8	33.8	14.0	7.1	2.1	12.4	23.5	64.3
75th percentile	69.9	64.4	25.2	13.3	4.5	23.4	41.4	126.6
95th percentile	138.6	137.7	61.4	32.8	15.8	148.6	92.9	247.8
Apparent EAR for women 15–49 years old obtained from fortified wheat flour (percent of EAR)								
Micronutrient (EAR value)								
1. Iron (26.5 mg/kg), assuming:								
a. Low (5%) bioavailability								
Mean	10	10	4	2	1	7	7	18
5th percentile	1	1	1	0	0	0	1	1
25th percentile	3	3	2	1	0	1	3	4
50th percentile	7	7	3	1	0	3	5	13
75th percentile	15	13	5	3	1	5	9	26
95th percentile	29	29	13	7	3	31	19	51
b. Intermediate (10%) bioavailability								
Mean	20	19	9	5	2	14	14	35
5th percentile	2	1	2	1	0	1	2	2
25th percentile	5	5	4	1	0	2	5	9
50th percentile	14	14	6	3	1	5	10	26
75th percentile	28	26	10	5	2	10	17	52
95th percentile	56	56	25	13	6	61	38	101
2. Folic Acid (188 mg/kg)								
Mean	47	45	20	11	4	33	32	83
5th percentile	4	3	4	1	0	2	6	5
25th percentile	12	12	8	3	1	6	13	20
50th percentile	33	32	13	7	2	12	23	62
75th percentile	67	62	24	13	4	22	40	121
95th percentile	133	132	59	31	15	142	89	237
3. Vitamin B_1 (0.9 mg/kg)								
Mean	34	32	15	8	3	24	23	60
5th percentile	3	2	3	1	0	2	4	4
25th percentile	8	9	6	2	1	4	9	14
50th percentile	24	23	10	5	1	9	16	44
75th percentile	48	44	17	9	3	16	29	87
95th percentile	95	95	42	23	11	102	64	171

continued

TABLE 2. Apparent EAR for women 15–49 years old for micronutrients obtained from foritfied wheat flour (includes only households purchasing some of the selected food item) *(continued)*

Micronutrient type/household apparent consumption level	Sweet bread	French bread	Sliced bread	Crackers	Cakes	Wheat tortilla	Wheat flour	All wheat flour products (FWFE definition #1)
4. Vitamin B_2 (0.9 mg/kg)								
Mean	23	22	10	5	2	16	16	41
5th percentile	2	1	2	1	0	1	3	2
25th percentile	6	6	4	2	1	3	6	10
50th percentile	16	16	7	3	1	6	11	30
75th percentile	33	30	12	6	2	11	19	59
95th percentile	65	64	29	15	7	69	43	116
5. Vitamin B_3 (11 mg/kg)								
Mean	25	23	11	6	2	17	17	44
5th percentile	2	2	2	1	0	1	3	3
25th percentile	6	6	4	2	1	3	7	10
50th percentile	17	17	7	4	1	6	12	32
75th percentile	35	32	13	7	2	12	21	63
95th percentile	69	69	31	16	8	74	46	124

EAR, Estimated Average Requirement; FWFE, Fortified Wheat Flour Equivalent
No adjustment is made in these calculations for losses that may occur in transporting, storing or food preparation.

flawed approach would result in 5,353,636 households, slightly more than twice 2,653,000, the total number of households that exist in Guatemala.

The fortified wheat flour composite measure enables all of the households that eat any of the seven fortified wheat flour-based products to be identified, but ensures (by construction) that each household is counted only once. In the case of sugar—the only food, other than salt, that is mandated to be fortified in Guatemala—the analysis of coverage is more straightforward, owing primarily to data constraints. Although sugar—like wheat flour—is used as an input into the production of other foods, the ENCOVI does not provide adequately detailed information about other final consumer food products that contain significant amounts of fortified sugar to enable their investigation. The coverage of fortified sugar, therefore, is analyzed in this study using only refined sugar as a final consumer good and therefore is underestimated in this study.*

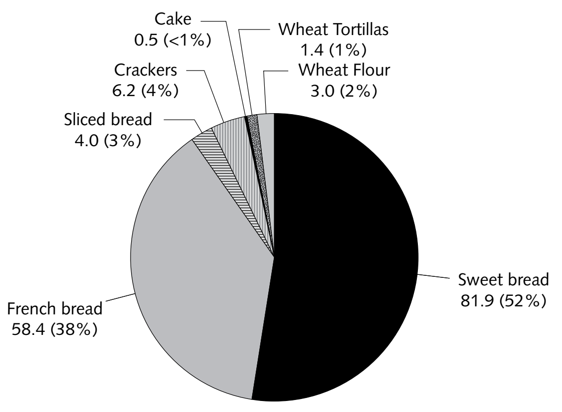

FIG. 2. The food vehicle sources of the total fortified wheat flour equivalent consumed by Guatemalans, 2006 (metric tons per day)

Additional micronutrient intakes in grams per FACE unit per day and as a percentage of EAR

To estimate the additional intake of micronutrients owing to the consumption of a fortified food, it is necessary to know the level of consumption of the fortified food, the mix of micronutrients that the food is being fortified with, and the amount of each of the micronutrients that is in the fortification formula. If person-specific, micronutrient-specific deficiency data were available, we would calculate the number of persons whose deficiency had been eliminated by

* The most important industrial use of sugar in Guatemala is in the manufacturing of soft drinks, which is estimated to account for the use of as much as 25% to 33% of total refined sugar (Omar Dary, personal communication, May 25, 2007). It is thought, however, that much of the vitamin A is lost in the process of producing soft drinks. Thus, the bias resulting from not including sugar used as an input into the production of other foods is not large in terms of the additional vitamin A intake, although the associated costs of fortifying sugar are still incurred. Guatemala is considering modifying its sugar fortification law to exempt sugar that is sold to soft drink producers from the mandate that it be fortified with vitamin A.

the fortification program or the magnitude of the reduction in the deficiency gap. These data, however, are unfortunately not available. The best that we can do is to analyze the additional intake of specific micronutrients at different levels of consumption of the food vehicle and then calculate the percentage of the Estimated Average Requirement (EAR) that the additional intake represents at each of those different levels of consumption.

Guatemala's wheat flour fortification formulation contains iron 55 mg/kg, folic acid 1.8 mg/kg, vitamin B_1 6.2 mg/kg, vitamin B_2 4.2 mg/kg, and vitamin B_3 55 mg/kg. Multiplying these fortification levels by the consumption levels of the seven individual wheat flour-containing food items and the composite measure of the seven items yields the estimated additional micronutrient intake levels associated with each level of food consumption.* For each micronutrient, dividing the resulting product by the EAR of the micronutrient (identified in the micronutrient-specific heading to each section in the lower portion of **table 2**) yields the additional apparent EAR obtained from fortified wheat flour; these are reported in **table 2** as estimated percentages of the EAR.

Two alternative EAR estimates are used for iron. One assumes that the bioavailability of iron is low (5%). The second assumes that the bioavailability level is intermediate (10%) [2] Given the composition of the Guatemalan diet, it is likely that for most persons, the bioavailability of iron is low [2]. As may be seen in **table 2**, at the mean and median levels of apparent daily consumption per FACE unit, wheat flour fortification delivers 18% and 13% of the EAR of iron, assuming low bioavailability, and 35% and 26% of the EAR of iron, assuming intermediate bioavailability. These are conditional means and medians, and they do not take into account the 8% of the households that do not consume any fortified wheat flour product, nor do they make any adjustment for losses that may occur in transporting or storing the fortified food or in food preparation.

Table 3 presents the additional vitamin A intake resulting from apparent consumption of sugar in the previous 15-day period. At the median level of 112 g of sugar per FACE unit per day, the current mandated sugar fortification level results in an additional daily intake of 1,679 μg of vitamin A, the equivalent of 470% of the EAR for a woman 15 to 50 years of age.

The relatively high level of additional vitamin A intake attributable to eating fortified sugar is due to two factors: the high level of per capita sugar consumption and the high level of vitamin A fortification. The FAO/WHO Guidelines on Food Fortification with Micronutrients [2], for example, suggest a fortification level of 12 mg/kg of sugar (compared with Guatemala's mandated level of 15 mg/kg), and they consider per capita consumption levels of 10, 20, and 60 g/day at the 5th, 50th and 95th percentiles. In contrast, Guatemala's level of vitamin A fortification is 25% greater and its sugar consumption levels are three to five times greater at each of these consumption percentile benchmarks [2]. Furthermore, Guatemala's 95th percentile consumption level is 287 g/day. This is exactly equal to the maximum value of the high range of sugar consumption defined by the food-frequency questionnaire for the purpose of setting fortification levels so that they vary inversely with consumption levels.

* The wheat flour-related impact calculations do not include any adjustment for losses.

TABLE 3. Additional apparent daily intake of vitamin A from consuming fortified sugar (includes only households purchasing some sugar)

Households purchasing		
Number	2,036,206	
Percent	77%	
Amount purchased	Grams/FACE/day	
Mean	133	
5th percentile	37	
25th percentile	75	
50th percentile	112	
75th percentile	165	
95th percentile	287	
Additional vitamin A intake at different apparent consumption levels: fortifying at 15 μm RE/kg	REs/FACE/Day	
	Assuming no losses	Assuming 30% losses
Mean	1,988	1,392
5th percentile	557	390
25th percentile	1,124	787
50th percentile	1,679	1,176
75th percentile	2,474	1,732
95th percentile	4,310	3,017
Apparent percent EAR for vitamin A for women 15–50 years old obtained from fortified sugar (357 μm RE)	Percent EAR	
	Assuming no losses	Assuming 30% losses
Mean	557%	390%
5th percentile	156%	109%
25th percentile	315%	220%
50th percentile	470%	329%
75th percentile	693%	485%
95th percentile	1,207%	845%

EAR, Estimated Average Requirement; FACE, Female Adult Consumption Equivalent; RE, retinol equivalent

The upper limit (UL) for vitamin A intake is 3,000 μg. At the 95th percentile level of sugar consumption, the additional intake of vitamin A from fortified sugar is 4,310 μg. That is, the amount of vitamin A intake from consuming just fortified sugar—exclusive of any other sources of vitamin A—exceeds the UL. This suggests that the level at which sugar is being fortified with vitamin A may be too high; it may be putting some Guatemalans at risk for excess intake of vitamin A. Before rushing to this conclusion, however, and urging the rolling back of vitamin A fortification levels in sugar, this important concern warrants more careful analysis and a thorough vetting by nutrition and public health specialists.

First, it must be recognized that that the additional intake estimates just discussed do not assume any losses of vitamin A.* If it is assumed that 30% of vitamin A is lost in the marketing and food preparation processes before the sugar is eaten, then the 95th percentile level of 287 g of sugar per FACE unit per day results in an additional intake of "only" 3,017 μg of vitamin A, less than the UL. It must be recognized, however, that this is only an assumption, and that if losses are greater than 30% it may not be advisable to reduce the level at which sugar is fortified with vitamin A. At the same time, however, it must also be recalled that the estimated quantity of sugar consumed presented here is underestimated because (as noted earlier) it includes only sugar that is consumed as a final consumer product; it does not include the consumption of fortified sugar that is used in producing other foods that might also be consumed, nor does it include sugar consumed outside the home.

Further heightening concern about the level of vitamin A fortification of sugar is the fact that no other sources of vitamin A intake are considered in this analysis. The only source of relatively recent data on vitamin A intake is from an analysis of the 2000 ENCOVI by Bermudez [13]. Using the Institute of Nutrition of Central America and Panama (INCAP) food composition tables to estimate the household consumption of vitamin A from "all" sources, Bermudez estimated the mean daily household vitamin A intake to be 8,299 μg RE. This is the equivalent of a daily intake per FACE unit of 2,290 μg. This is the mean value, which suggests that the level of vitamin A intake from dietary sources other than fortified sugar is likely to be sufficiently high that one cannot but conclude that there is a public health concern that the current level at which sugar is fortified with vitamin A is very likely to be too high, and urgently needs to be reassessed.

* In discussing the issue of adjusting for losses, the FAO/WHO Guidelines [2, page 298] state: "A more accurate calculation may consider losses during distribution and storage, as well as losses during food preparation. However, because losses vary hugely according to conditions and situations, and because allowance is often made to compensate for these losses (i.e., an overage), it is usually acceptable to use this simplified approach"—that is, to not make any adjustments.

An evidence-based assessment of the current Guatemalan fortification program

This section presents an evidence-based assessment of the potential benefits of introducing some modifications in the current Guatemalan fortification program. Three scenarios will be investigated:

» Scenario 1: Mandating the fortification of semolina flour with the same formula currently used to fortify all other wheat flour;

» Scenario 2: Changing the wheat flour fortification formula to include (individually or in some combination) vitamin B_6, vitamin B_{12}, and zinc;

» Scenario 3: Mandating the fortification of semolina flour with the alternative formulations examined for all other wheat flour.

Scenario 1: Fortifying semolina flour with the current wheat formulation

As already noted, the flour used to produce noodles and pasta, semolina, is not currently fortified in Guatemala. Noodles were purchased by 68% of all Guatemalan households during the 15-day recall period, including 68% of rural, 73% of indigenous, and 63% of extremely poor households. As judged by this demand criterion, fortifying semolina looks promising as a vehicle for increasing coverage, particularly among the persons and households most likely to be in need due to micronutrient deficiencies.

The top portion of **table 4** presents a second wheat flour composite measure (labeled "FWFE definition 2" in the table). Definition 2 includes the seven food items included in the first composite measure (FWFE definition 1), and in addition includes the flour that is used to produce noodles. Grams of noodles purchased per household in the previous 15-day period were converted into grams per FACE unit per day, assuming that 90% of the weight of dry noodles is semolina flour (personal communication, Quentin Johnson, Quican Inc.). It was assumed that semolina flour would be fortified using the same formulation as that currently used to fortify all wheat flour other than semolina. For each household, the semolina flour wheat equivalent was added to the all other wheat flour equivalent to provide an all wheat flour equivalent variable.

Whereas the addition of semolina flour to the wheat flour already fortified increases the number of households purchasing some fortified wheat flour by only 59,178 (2%), it contributes to much larger than proportionate increases in the amounts of total flour purchases (shown in column 4 in the top portion of **table 4**), owing to the relatively large amount of noodles

TABLE 4. Apparent EAR for women 15–49 years old for micronutrients that would be obtained from foritfiying semolina flour per female adult consumption equivalent (includes only households purchasing some noodles/pasta)

Micronutrient type/household apparent consumption level	Noodles/pasta	All currently fortified wheat flour products (FWFE definition #1)	All currently fortified wheat flour products plus semolina flour (FWFE definition #2)	Percentage increase if semolina flour were fortified
Households purchasing:				
Number	1,809,997	2,445,630	2,504,808	2%
Percent	68%	92%	94%	
Amount of FWFEs purchased				
Mean	29.4	87.0	106.2	22%
5th percentile	6.7	5.1	10.0	95%
25th percentile	13.9	20.9	36.9	77%
50th percentile	22.5	64.3	83.5	30%
75th percentile	37.3	126.6	148.5	17%
95th percentile	74.6	247.8	280.6	13%
Apparent EAR for women 15–49 years old obtained from fortified wheat flour (% EAR)				
Micronutrient (EAR value)				
1. Iron (26.5 mg/kg), assuming:				
a. Low (5%) bioavailability				
Mean	6.11	18.06	22.05	22%
5th percentile	1.40	1.06	2.08	95%
25th percentile	2.89	4.33	7.66	77%
50th percentile	4.68	13.35	17.32	30%
75th percentile	7.74	26.27	30.83	17%
95th percentile	15.48	51.43	58.23	13%
b. Intermediate (10%) bioavailability				
Mean	12.22	36.12	44.10	22%
5th percentile	2.79	2.13	4.15	95%
25th percentile	5.77	8.67	15.32	77%
50th percentile	9.36	26.69	34.65	30%
75th percentile	15.48	52.54	61.65	17%
95th percentile	30.95	102.86	116.47	13%
2. Folic acid (188 mg/kg)				
Mean	28.18	83.32	101.71	22%
5th percentile	6.44	4.90	9.57	95%
25th percentile	13.31	19.99	35.34	77%
50th percentile	21.59	61.57	79.92	30%
75th percentile	35.69	121.18	142.20	17%
95th percentile	71.39	237.26	268.64	13%
3. Vitamin B_1 (0.9 mg/kg)				
Mean	202.73	599.48	731.82	22%
5th percentile	46.36	35.28	68.88	95%
25th percentile	95.77	143.83	254.25	77%
50th percentile	155.33	443.02	575.01	30%
75th percentile	256.83	871.90	1023.15	17%
95th percentile	513.65	1707.13	1932.87	13%

continued

TABLE 4. Apparent EAR for women 15–49 years old for micronutrients that would be obtained from foritfiying semolina flour per female adult consumption equivalent (includes only households purchasing some noodles/pasta) *(continued)*

Micronutrient type/household apparent consumption level	Noodles/pasta	All currently fortified wheat flour products (FWFE definition #1)	All currently fortified wheat flour products plus semolina flour (FWFE definition #2)	Percentage increase if semolina flour were fortified
4. Vitamin B_2 (0.9 mg/kg)				
Mean	137.34	406.10	495.75	22%
5th percentile	31.40	23.90	46.66	95%
25th percentile	64.87	97.43	172.24	77%
50th percentile	105.22	300.11	389.52	30%
75th percentile	173.98	590.64	693.10	17%
95th percentile	347.96	1156.44	1309.37	13%
5. Vitamin B_3 (11 mg/kg)				
Mean	14.71	43.51	53.12	22%
5th percentile	3.36	2.56	5.00	95%
25th percentile	6.95	10.44	18.45	77%
50th percentile	11.27	32.15	41.73	30%
75th percentile	18.64	63.28	74.26	17%
95th percentile	37.28	123.90	140.29	13%

EAR, Estimated Average Requirement; FWFE, Fortified Wheat Flour Equivalent
No adjustment is made in these calculations for losses that may occur in transporting, storing or food preparation

purchased by those who purchase them. At the mean level of consumption of those households purchasing some wheat flour, it results in a 22% increase in the amount of flour purchases and at the median the increase is 30%.

The variations in the quantities of noodles and the quantities of all other wheat flour products purchased at different levels of consumption suggest that noodles and all other wheat flour products are substitutes, i.e., a person who purchases more of one product is likely to purchase less of the others. Thus, at low levels of consumption of non-semolina flour-based products, the addition of fortified noodles results in large percentage increases in wheat flour fortification-derived micronutrient intakes. For instance, at the 5th percentile of consumption of currently fortified wheat flour, the fortification of semolina results in a 95% increase in the quantity of fortified flour consumed and a 95% increase in the intake of fortification-derived micronutrient. At the 25th consumption percentile, the fortification of semolina adds 77%, a still substantial but smaller increase. At the 50th percentile it adds 30%, at the 75th percentile 17%, and at the 95th percentile 13%.

In sum, the distribution of the amount of consumption of noodles is inversely related to that of all other fortified wheat flour-based products: when one goes up, the other goes down. This makes them complementary in terms of the amount of micronutrients they deliver, in the sense that the fortification of semolina flour will increase the intake of micronutrients most among those who currently obtain the least from currently fortified wheat flour, and it will increase the intake least among those who currently obtain the most additional micronutrient intake from currently fortified wheat flour. In short (abstracting from the issue of who is most in need of the micronutrients—since we have no data to address this fundamentally important issue), the consumption patterns of these two "products" are ideal: households that consume small quantities of all the other fortified wheat flour and thus obtain relatively small amounts of additional intake of micronutrients from fortification at present are also the households that consume the most semolina, and thus will obtain relatively large amounts of additional intake of micronutrients from semolina. The fortification of semolina flour will help those who are most in need of help—as judged by the amount of additional micronutrient intakes from wheat flour—and will do so without the undue burdening of those who are already consuming other wheat flour products or those who are already consuming large quantities of them.

As may be seen in **table 4**, if semolina flour is fortified, at the median it will result in a 30% increase in the EAR of iron of women 15 to 49 years of age, and it will result in wheat flour providing 17.3% of the EAR of iron to women with diets containing iron of low bioavailability and 34.6% of the EAR of iron to women with diets containing iron of intermediate bioavailability. In the case of the other micronutrients, at the median the fortification of semolina flour will result in the consumption of fortified flour providing 80% of the EAR of folic acid, 575% of the EAR of vitamin B_1, 390% of the EAR of vitamin B_2, and 41% of the EAR of vitamin B_3.

Scenario 2: Modify the current fortification formulation

The second scenario examined is the modification of the current wheat flour fortification formula to include (individually or in some combination) vitamin B_6, vitamin B_{12}, and zinc. The levels of fortification (in milligrams per kilogram of wheat flour) examined are vitamin B_6 6.0, vitamin B_{12} 0.02, and zinc 50.*

At the median apparent consumption level of currently fortified wheat flour-based products, the additional daily intake of these four micronutrients would be vitamin B_6 0.39 mg; vitamin B_{12} 0.0013 mg; and zinc with low bioavailability 3.22 mg, with intermediate bioavailability 6.43 mg .**

Column 8 of **table 5** shows that for women 15 to 49 years of age, these additional median intake levels would translate into the delivery of the following percentages of EAR: vitamin B_6 36%; vitamin B_{12} 64%; and zinc with low bioavailability 78%, with intermediate bioavailability 157%.

Scenario 3: Fortifying semolina flour with the modified formulation

The third scenario examines extending the modified flour fortification formulation of adding vitamin B_6, vitamin B_{12} , and zinc to semolina flour. At the median apparent consumption level of currently fortified wheat flour-based products, the additional daily intake of these three micronutrients would be vitamin B_6 0.14 mg; vitamin B_{12} 0.0005 mg; and zinc with low bioavailability 1.13 mg, with intermediate bioavailability 2.25 mg.

As may be seen in column 9 of **table 5**, for women 15 to 49 years of age, these additional intake levels due to the fortification of semolina would translate into the delivery of the following increases of EAR from the levels derived from the currently fortified wheat flour fortification formulation: vitamin B_6 12%; vitamin B_{12} 23%; and zinc with low bioavailability 27%, with intermediate bioavailability 55%.

Table 5 may also be used to explore alternative ways of combining different fortification formulations of semolina flour with currently fortified wheat flour or with new formulations for the food items produced using currently fortified wheat flour by simply adding

* These levels are the "suggested fortification levels" obtained from applying the Food Fortification Formulator [14] and entering the 5th, 50th, and 95th percentiles of Guatemalan wheat flour apparent consumption for definition 1 of wheat flour.

** The bioavailability of zinc is high from diets rich in animal protein, moderate from diets rich in legumes and pulses, and low from diets poor in animal protein or zinc-rich plant foods (FAO/WHO, 2006 page 148, footnote f).

TABLE 5. Apparent EAR for women 15–49 years old for micronutrients that would be obtained from foritfied wheat flour if Vitamin A, B_6, B_{12} and zinc were added to the fortification formula (includes only households purchasing some of the selected food item)

Micronutrient type/ household apparent consumption level	(1) Sweet bread	(2) French bread	(3) Sliced bread	(4) Crackers	(5) Cakes	(6) Wheat tortilla	(7) Wheat Flour	(8) All currently fortified wheat flour products (FWFE definition #1)	(9) Introducing fortified semolina flour	(10) All currently fortified wheat flour products + fortifying semolina (FWFE definition #2)
Households purchasing:										
Number	2,273,832	1,716,948	258,214	770,351	158,070	54,240	121,981	2,445,630	1,809,997	2,504,808
Percent	86%	65%	10%	29%	6%	2%	5%	92%	68%	94%
Amount of FWFEs purchased										
Mean	49.4	46.6	21.3	11.1	4.3	34.1	33.5	87.0	29.4	106.2
5th percentile	3.8	3.1	4.2	1.4	0.4	2.2	5.9	5.1	6.7	10.0
25th percentile	12.1	13.0	8.8	3.5	1.1	6.0	13.1	20.9	13.9	36.9
50th percentile	34.8	33.8	14.0	7.1	2.1	12.4	23.5	64.3	22.5	83.5
75th percentile	69.9	64.4	25.2	13.3	4.5	23.4	41.4	126.6	37.3	148.5
95th percentile	138.6	137.7	61.4	32.8	15.8	148.6	92.9	247.8	74.6	280.6

Apparent EAR for women 15–49 years old obtained from fortified wheat flour										
Micronutrient (EAR value)										
1. Vitamin B_6 (1.083 gm/kg)										
Mean	27	26	12	6	2	19	19	48	16	59
5th percentile	2	2	2	1	0	1	3	3	4	6
25th percentile	7	7	5	2	1	3	7	12	8	20
50th percentile	19	19	8	4	1	7	13	36	12	46
75th percentile	39	36	14	7	2	13	23	70	21	82
95th percentile	77	76	34	18	9	82	51	137	41	155
2. Vitamin B_{12} (0.002 mg/kg)										
Mean	49	47	21	11	4	34	33	87	29	106
5th percentile	4	3	4	1	0	2	6	5	7	10
25th percentile	12	13	9	4	1	6	13	21	14	37
50th percentile	35	34	14	7	2	12	24	64	23	83
75th percentile	70	64	25	13	4	23	41	127	37	149
95th percentile	139	138	61	33	16	149	93	248	75	281
3. Zinc (4.1 mg/kg)										
a. Low bioavailability										
Mean	60	57	26	14	5	42	41	106	36	130
5th percentile	5	4	5	2	1	3	7	6	8	12
25th percentile	15	16	11	4	1	7	16	25	17	45
50th percentile	42	41	17	9	3	15	29	78	27	102
75th percentile	85	79	31	16	5	29	51	154	45	181
95th percentile	169	168	75	40	19	181	113	302	91	342
b. Intermediate bioavailability										
Mean	120	114	52	27	10	83	82	212	72	259
5th percentile	9	8	10	3	1	5	14	12	16	24
25th percentile	30	32	21	9	3	15	32	51	34	90
50th percentile	85	82	34	17	5	30	57	157	55	204
75th percentile	171	157	61	32	11	57	101	309	91	362
95th percentile	338	336	150	80	39	362	227	604	182	684

EAR, Estimated Average Requirement; FWFE, Fortified Wheat Flour Equivalent
No adjustment is made in these calculations for losses that may occur in transporting, storing or food preparation.

any the various possible permutations of the three micronutrients.

Discussion and conclusions

Comparing the results of using conditional versus unconditional consumption levels in measuring the impact of fortification

As already noted, the departure point of this study was the 2007 study of Imhoff-Kunsch et al. [4]. That study estimated the impact of the Guatemalan wheat flour fortification program using unconditional consumption levels and concluded that the program's impact was minor. As was also noted earlier, however, the use of unconditional consumption levels to assess the impact of the program by Imhoff-Kunsch and colleagues is ill-founded and underestimates the program's impact. Their impact measure is a single metric that dilutes the estimated impact of the program by including in the calculation the consumption levels of persons who do not consume any wheat flour products. Clearly, the fortification program does not have any impact on the nutritional status of those who do not consume any fortified products. That should be explicitly acknowledged and the nonconsumers should be left out of the calculation.

Accurately depicting the impact of the program requires at least two measures: the coverage of the program—which is the number of households or individuals or the proportion of the population that consumes some of the fortified food products—and the additional micronutrient intake (measured in milligrams per kilogram of food or in terms of the percentage of the EAR that is provided by the intake of foods that now have a higher micronutrient content) of those who consume some of the fortified food products. To include the nonconsumers in the impact calculation lowers the estimated consumption levels that are commonly used reference points at which impacts are characterized, namely, the mean, median, and cumulative consumption percentiles. How large the difference in the conditional and unconditional consumption levels is, other things being equal, is a function of the proportion of the population that consumes some of the food. The smaller the proportion of the population that consumes some of the food, the greater will be the differences between the conditional and unconditional consumption levels.

Table 6 shows the magnitude of the differences between the conditional and unconditional mean and median consumption levels of the fortified foods analyzed in this study. In the case of sugar, the conditional mean is 133 g per FACE unit per day, 30% greater than the unconditional mean value of 102. The conditional median is 70% greater than the unconditional. In the case of the seven food items that contain some fortified wheat flour, the conditional means are all substantially greater than the unconditional means; they vary from a low—the case of sweet bread, in which the conditional mean is 17% greater than the unconditional mean (42.3 vs. 49.4 g per FACE unit per day)—to wheat flour, in which the conditional mean is 22 times greater than the unconditional (1.5 vs. 33.5 g per FACE unit per day). As can be seen in **table 6**, the differences in the medians are even greater.

In the case of a fortification vehicle such as wheat flour, which is measured as the sum of a number of wheat flour-containing foods, the magnitude of the difference between the conditional and unconditional mean consumption levels of the composite measure of wheat flour will depend upon the proportion of the population that consumes each of the foods, but it will also depend on the relative quantities of the foods that are consumed and the mix of food types and food quantities consumed across households. In the case of Guatemala, even though the seven wheat flour-containing foods have conditional means that are between 17% and 2200% greater than the unconditional means, the

TABLE 6. Comparisons of conditional and unconditional mean and median consumption levels of fortification vehicles (grams per female adult consumption equivalent per day)

Food	Conditional mean	Unconditional mean	Conditional as a % of unconditional mean	Conditional median	Unconditional median	Conditional as a % of unconditional median
Sweet bread	49.4	42.3	117%	34.8	26.0	134%
French bread	46.6	32.1	145%	33.8	11.5	294%
Sliced bread	21.3	2.1	1,014%	14	0.0	—
Crackers	11.1	3.2	347%	7.1	0.0	—
Cakes	4.3	0.3	1,433%	2.1	0.0	—
Wheat tortillas	34.1	16.4	208%	12.4	0.0	—
Wheat flour	33.5	1.5	2,233%	23.5	0.0	—
Wheat flour composite (#1)	87.0	80.2	108%	64.3	55.2	116%
Sugar	133.0	102.0	130%	112	66.4	169%

differences in the conditional and unconditional means of the wheat flour composite measure (labeled FWFE definition 1 in the analysis above), are much smaller than any of the differences in the seven constituent components because of the varying quantities and different patterns of consumption across Guatemalan households. The conditional mean is 87.0, just 8% greater than the unconditional mean of 80.2.

Direct comparison between the impact of wheat flour fortification estimated by Imhoff-Kunsch and colleagues and the impact estimated by this study is not straightforward. The two studies have a number of methodological differences. More specifically, compared with this study, Imhoff-Kunsch et al. use EARs for iron that are 6.5% less (those used here are from the Food Fortification Formulator, a more recent work of one of the Imhoff-Kunsch team [4]; use fortification levels that are 18% less (those used here are the current legal standard in Guatemala); use estimates of the wheat flour content of bread that are 28% more (the source of those used here is a highly regarded wheat flour specialist, Quentin Johnson, Quican Incorporated); and include only wheat flour, sweet bread, French bread, and sliced bread in their construction of the FWFE composite measure, whereas this study also includes crackers, cakes, and wheat tortillas (which together account for an increase in the quantity of wheat flour included in the analysis of about 6%).

Whereas the first two considerations above contribute to making the impact estimates of Imhoff-Kunsch and colleagues less than those presented here, the latter two considerations contribute to making them greater. The net effect of these differences, in combination with differences in the use of unconditional versus conditional consumption levels, results in the impact of the wheat flour fortification program reported here being greater than that estimated by Imhoff-Kunsch and colleagues. The fortification program covers 92% of the Guatemalan population, and among the 92% of the population that consumes some wheat flour-based products, at the median FWFE consumption level, it accounts for 13% and 62% of the EARs for iron (assuming 5% iron bioavailability) and folic acid, respectively, among women 15 to 49 years of age. These estimates are 2.4 and 1.9 times higher than the estimates of Imhoff-Kunsch et al., respectively.

Putting the key findings and the HIES-based tool in a longer-term perspective

Food fortification has a long history in Guatemala—one that began more than three decades ago. Given this long history, Guatemala's micronutrient deficiency patterns—the incidence, prevalence, and severity of deficiencies—no doubt reflect the impact of this already long-standing program. Few would argue that the Guatemalan fortification program has not been successful in improving the nutrition status of Guatemalans. What has been the exact nature of the impact of fortification efforts on micronutritional status in quantitative terms, however, is unknown. Similarly, the current role of fortification as a determinant of Guatemalan micronutrient status is unknown. Although there are some ongoing efforts to monitor the vitamin A content of sugar and the iron content of wheat flour, there has been inadequate monitoring of Guatemalans' nutritional status.

It is likely that the impact of fortification on the micronutrient deficiency patterns of Guatemalans has changed over time as the fortification program has evolved, as Guatemalans' eating habits have changed and as food manufacturing practices and the nature of food markets in Guatemala have changed. Furthermore, if one looks at the "bigger picture," it is clear that there has been enormous progress in Guatemala over recent years, as measured by a number of important socioeconomic indicators: average family incomes have increased; general, maternal, infant, and under-five mortality rates have fallen; and general health status has improved. It is likely that many of these advances have affected the nutritional status of Guatemalans, too. For the most part, they have probably improved it, but again, the lack of empirical data prevents our being able to understand more precisely and more definitively what has happened.

In short, the design and operation of a fortification program should not be considered a one-time event. Fortification programs play a potentially important role in helping to promote good health and nutrition, but what they should consist of—how they should be structured and what they should do—needs to evolve over time. As society changes, the determinants of nutrition change, and as they do, fortification programs—which are living instruments for improving public health and nutrition—should change too. How they need to change depends on the outcome of a number of complex, interrelated factors. As a country's dietary needs, dietary habits, food manufacturing practices, and food markets change, they are likely to affect nutritional status. They may create new nutritional deficiencies or other types of public health nutrition concerns. It is essential, therefore, that fortification programs become more evidence-based so that these concerns can be identified and addressed on an ongoing basis. There is a need for greater use of evidence in the design and implementation of fortification programs so as to ensure that they continue to serve as a tool for improving public health and nutrition and to better ensure that they can become more effective and more efficient in doing so. In addition to the already noted finding that the impact of the wheat flour fortification program is considerably greater than had previously been thought, there are two other key findings:

» The level at which sugar is fortified with vitamin A may be excessive and should be reviewed;

» Fortifying semolina flour would extend the benefits of wheat flour fortification to 60,000 households that currently do not benefit from wheat flour fortification. Fortifying semolina would also increase the benefits of the fortification program to a total of 68% of the population—including 63% of the extremely poor—and the greatest benefits would go to those wheat flour consumers who currently benefit the least from consuming fortified wheat flour products.

These findings provide telling examples of why an evidence-based approach, coupled with ongoing monitoring of the public's health and nutrition status, is essential.

The absence of information on food consumption has stymied the development of many fortification programs. Moreover, in many countries that already have fortification programs—including Guatemala—there is growing clamor from private sector partners for more evidence with which to set fortification levels and with which to assess the impact of the program. More rigorous analysis and more detailed understanding of the programs so as to ensure greater accountability and better cost controls are the order of the day.

HIES, ENCOVI, and similar national household surveys that collect information on food expenditures are now routinely conducted once every 3 to 5 years in nearly every country of the world. ENCOVI-like surveys—though not without some shortcomings of their own—constitute an important empirical data source that provides information on the distribution of food consumption patterns at a national level, at relatively minor additional cost. As such, HIES should become part of the standard set of tools that are used in the design, monitoring, and analysis of fortification programs. At the same time, attention needs to be devoted to assessing their quality and fine-tuning them so that they can provide better, more precise information with which to inform the design and monitoring of food and nutrition policy.

ANNEX. FAO factors for calculating Female Adult Food Consumption Equivalents (FACE)

Age (yr)	Males	Females
< 1	0.37	0.37
1–3	0.62	0.62
4–6	0.84	0.84
7–9	1.00	1.00
10–12	1.18	1.07
13–15	1.32	1.14
16–19	1.40	1.05
≥ 20	1.37	1.00

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