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Wheat Flour Fortification Is Unlikely to Benefit the Neediest in Guatemala[1]

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Abstract

The potential impact of wheat flour fortification with iron and folic acid was assessed using data about food purchases from the nationally representative 2000 Guatemalan Living Standards Measurement Survey. Of 7265 households, 35% were indigenous and 57% rural; 11% were extremely poor, 35% were poor, and 54% were nonpoor. The percentage of households that purchased wheat flour, sweet bread, French rolls, and sliced bread in the previous 15 d was 10, 88, 59, and 11%, respectively. The median amount of fortified wheat flour equivalents in purchased foods was 50 g/d per adult equivalent; fortified wheat flour equivalents were 7, 25, and 110 g/d for the poverty groups, 16 g/d in indigenous households and 24 g/d in rural households. Wheat flour fortification contributed 2.3 mg/d of iron and 90 μg/d of folic acid per adult equivalent. Assuming 5% bioavailability, wheat flour fortification provided 2% of the recommended dietary allowance (RDA) and 6% of estimated average requirement (EAR) iron levels for women of reproductive age; values were 1, 3, and 12% of EAR levels for the poverty groups, respectively. Wheat flour fortification met 26% of folic acid RDA and 33% of EAR levels for women; values were 5, 16, and 71% of EAR levels for the poverty groups, respectively. In conclusion, the impact of fortification is likely to be substantial for folate status in nonpoor and urban women but limited in the case of iron status among all social groups. The poorest, rural, indigenous populations who suffer the highest burden of nutritional deficiencies likely benefit least from wheat flour fortification. J. Nutr. 137: 1017–1022, 2007.

Introduction

Iron-deficiency anemia is a major global public health problem, and many populations in developing countries, including Guatemala, suffer an especially high burden of anemia. Iron deficiency and iron-deficiency anemia can lead to impaired mental and motor development and behavioral problems in children, increased risk of adverse pregnancy outcomes (including increased risk of maternal mortality with severe iron-deficiency anemia), and decreased physical work capacity and productivity (1). Results from the Guatemalan National Maternal and Child Health Survey indicate that 20% of nonpregnant women of child-bearing age, and 40% of children aged 6–59 mo were anemic in 2002, down from 1998 estimates of 28 and 49%, respectively (2). The prevalence of anemia in Guatemala was highest in indigenous, rural, and poor populations. In 2002, 24% of indigenous Guatemalan women of child-bearing age were anemic compared with 18% of Ladino women (2).

Although national estimates of the incidence of neural tube defects (NTD)[4] are unavailable for Guatemala, the rate is estimated to be high in certain areas of the country. The Epidemiological Research Center in Sexual and Reproductive Health (CIESAR) in Guatemala reports neural tube defects rates of 106 per 10,000 live births in Quetzaltenango, a city located in the Guatemalan highlands (Dr. Edgar Kestler, CIESAR, personal communication).

Low maternal plasma folate is associated with a higher risk of NTD (3). Daily supplementation with folic acid (400 μg) during early pregnancy decreases the risk of neural tube defects (3–5). Also, fortification of food with folic acid has been shown to improve folate status in women, which is linked to reduced rates of neural tube defects in the United States, Chile, and Costa Rica (6–14).

Fortification, supplementation, and control of intestinal helminthic infections are among several strategies to combat iron deficiency. Several trials found that the consumption of iron-fortified staple foods or condiments improves iron status. Among the products studied were iron-fortified fish sauce (15), salt fortified with microencapsulated iron, iodine, and vitamin A (16), iron-fortified curry powder (17), iron-fortified soy sauce (18), iron-fortified milk and drinking water (19), and sugar fortified with vitamin A and iron (20). Information about the effectiveness of iron fortified flours is limited. An analysis of anemia in school-aged children suggested that fortification of wheat and corn flour in Venezuela in 1993 improved iron status and reduced anemia (18,21). Comparisons between countries

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[4] Abbreviations used: EAR, estimated average requirement; ENCOVI, Encuesta de Condiciones de Vida; FWFE, fortified wheat flour equivalents; RDA, recommended dietary allowance.

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with similar diets with or without iron-fortified flour suggest that flour fortification may be effective in decreasing anemia rates; for example, Chile, where flour is fortified with ferrous sulfate, has lower anemia rates than Argentina, where flour is not fortified (22).

Several Central American countries, including Guatemala, began to fortify wheat flour with iron in the early 1960s at a level of 28.7–36.6 mg/kg using reduced elemental iron (23). In the early 1990s, and in response to the persistently high prevalence of iron deficiency in the region, the level of fortification was increased to 50–60 mg/kg but in the form of atomized elemental iron. Unfortunately, this form of iron, which is iron ground to the same particle size as reduced iron, has extremely poor bioavailability. In 2002, all Central American countries agreed on uniform standards for fortification of wheat flour with iron, folic acid, thiamin, riboflavin, and niacin. Guatemala currently fortifies wheat flour with ferrous fumarate (45 mg/kg), a better fortificant than previously used, as well as with folic acid (1.8 mg/kg), thiamin (6.2 mg/kg), riboflavin (4.2 mg/kg), and niacin (55 mg/kg) (23). Routine monitoring indicates that wheat flour is being fortified at the specified fortification levels [C. Martinez, Instituto de Nutrición de Centro América y Panamá (INCAP), personal communication]. Though anemia rates decreased between 1998 and 2002 in Guatemala, it is unlikely that this was due to wheat flour fortification, because atomized elemental iron was used during this period (23).

Objective. We evaluated the potential impact of wheat flour fortification in Guatemala by estimating household consumption of wheat flour and ready-made breads among different socioeconomic groups, residences (urban vs. rural), and ethnic groups (indigenous vs. nonindigenous). We also explored whether fortification of additional food vehicles, such as pasta or rice, has the potential to further increase iron and folate intakes in more vulnerable populations. We addressed 2 primary programmatic questions: *1*) who purchases and therefore consumes and benefits from fortified wheat flour foods in Guatemala? and *2*) do other foods exist that are suitable fortification vehicles for targeting vulnerable populations?

Methods

We estimated household consumption of selected foods, including wheat flour and ready-made breads, using expenditure data from a population-based survey conducted in Guatemala. The Guatemalan Living Standards Measurement Survey [Encuesta de Condiciones de Vida (ENCOVI)] provides nationally representative cross-sectional data describing living standards such as access to food, household income, literacy, community infrastructure, and food acquisition (24). The ENCOVI survey was conducted in Guatemala from July through December 2000 and provides data from 7265 households (25). The analyses in this paper were a component of a larger project (The Prevention of Neural Tube Defects in Guatemala), which was approved by the Institutional Review Board of Emory University (IRB ID 205–2004).

We analyzed the following questions from the ENCOVI survey: "Did you purchase (food item) in the past 12 mo?" and "How much (food item) did you purchase in the last 15 d?" Data were weighted and analyzed accordingly so that appropriate population estimates could be made. Per capita food purchases were estimated by dividing the weight or quantity of food purchased per household per day by household adult equivalent units. To account for differences in gender and age composition in different households, we calculated household adult equivalent units using the INCAP daily energy requirement and household composition information in the survey (26). We designated the energy requirement of an 18 to 64-y-old male as the reference and weighted other age and gender groups based on their specific energy requirements. For example, 18 to 64-y-old men were assigned a weight of 1; 18 to 64-y-old women a weight of 0.677; and 10 to 11-y-old females a weight of 0.612. Household adult equivalent units were obtained by adding together all individual adult equivalent units in the household. Although these are technically "male" adult equivalent units, these values are conventionally known as "adult" equivalent units.

Household ethnicity was assigned based on the head of household's ethnicity, and socioeconomic status was as defined by the World Bank and based on levels of household purchasing power, with households classified as nonpoor, poor, or extremely poor (27,28). Households that could not afford to purchase the minimum "food basket" that supplied the minimum recommended energy per person per day were classified as extremely poor. Households that could purchase the minimum food basket plus a small amount of nonfood goods and services were classified as poor. And nonpoor-classified households could purchase the minimum food basket, plus nonfood goods and services.

Fortified wheat flour equivalents (FWFE) were estimated as the amount of fortified wheat flour contained in different breads. We assumed that sweet bread is composed of 65% wheat flour and that French rolls and sliced bread contain 77% wheat flour. Pasta, made from semolina, is not made from fortified flour. Median and mean per capita intakes of iron and folic acid were estimated by multiplying the fortification level by the amount of FWFE purchased per capita; intrinsic iron or folate, or the content naturally present in wheat flour, was not included.

Next, the percentage of iron and folate needs of women of reproductive age was estimated by expressing median nutrient intakes for women from fortification as a percentage of dietary recommendations. Women were selected as the group of interest because they, along with young children, are at greatest risk of anemia. Young children were not selected because their diets may differ markedly from those of the family.

A recent report from the WHO recommends the use of the estimated average requirement (EAR) for estimating nutrient contributions from fortification in populations (29). However, because of the pronounced right-skewed nature of iron requirements for menstruating women, the committee used the recommended nutrient intake (RNI), or the equivalent concept of the recommended dietary allowance (RDA), for this purpose. Although the RDA/RNI level is a better reference than the EAR for assessing the relative contribution of fortification to meeting the iron needs of women with high iron requirements, it underestimates the contribution of fortification in the case of other women. Neither of the levels is an ideal reference point and it becomes useful to examine the range of results obtained when both levels are used. The use of the RDA/RNI level will also underestimate the contribution of fortification in meeting the needs for iron, relative to those of folic acid and other nutrients for which the committee recommends the use of EAR levels. Thus, the contributions of fortification to satisfying iron needs were estimated relative to both EAR and RDA values and for consistency; this was done for folic acid as well. All reference values were taken or derived from Institute of Medicine reports (30,31).

Iron bioavailability is likely to be lower in Guatemalan diets than in diets of developed countries because of the common consumption of high-phytate foods. Because no specific bioavailability information is available for Guatemala, we estimated the proportion of the EAR and RDA for iron that was met by fortified wheat flour based on 2 levels of dietary bioavailability: 5% or 10%, denoted as poor and intermediate bioavailability, respectively, by FAO and WHO (29). Based on dietary patterns, it is likely that the bioavailability of iron may be poor in extremely poor and poor households and intermediate in nonpoor households. Diets in developed countries are assumed by FAO and WHO to have a bioavailability of 15%, a level that we considered unlikely for Guatemala. To estimate EAR levels at 5% and 10% bioavailability, the 50th percentile value of absorbed iron needs of adult, menstruating women (1.4 mg/d) was divided by 0.05 and 0.10, which yields EAR values of 28.2 and 14.1 mg/d, respectively. Similarly, the 97.5 percentile of absorbed iron needs (3.15 mg/d) was used to estimate RDA levels for adult menstruating women assuming 5% and 10% bioavailability, which yielded the values of 63.0 and 31.5 mg/d, respectively. We also estimated the contribution of wheat flour fortification to meeting the EAR and RDA for folate for women proposed by the Institute of Medicine: 320 μg/d and 400 μg/d of dietary folate equivalents (DFE), respectively (30). Based on the assumption that 1 μg folic acid = 1.7 μg DFE, the EAR and RDA values become 188 and 235 μg/d of folic acid (32). Finally, in estimating the percentage of EAR and RDA met for iron and folic acid, we expressed the nutrient contribution per adult equivalent unit multiplied by 0.677, the adult equivalent unit for women, as a percentage of the EAR and RDA for women.

Sample weights were taken into account and the statistical analyses were conducted using SAS 9.1 (SAS Institute). Due to the skewed distribution, we present both mean and median values for per capita purchases of foods made from fortified flour; for the same reason, we present median and interquartile range values (25th and 75th percentiles) when estimating the percentage of the EAR for iron and folic acid met through fortification.

Results

Our study described select demographic characteristics of the 7265 households included in the analysis, weighted to the Guatemalan population (**Table 1**). Forty-six percentage of households were either poor or extremely poor, 57% lived in rural areas, and 35% were indigenous. Overall, 21% of households purchased wheat flour in the previous 12 mo, and 10% purchased wheat flour in the past 15 d. Among all households, per capita wheat flour purchases were very low, 3 g/(person · d) (**Table 2**). Only 2% of households obtained wheat flour through means other than purchasing (as a gift or from own wheat cultivation) in the previous 12 mo.

Three types of ready-made bread products were included in the questionnaire: sweet bread, French rolls, and sliced bread. Sweet bread was purchased in the previous year by 94% of households and in the previous 15 d by 88% of households (Table 1). Compared with sweet bread, a lower proportion of households purchased French rolls or sliced bread. Purchases of ready-made bread products were lowest among poor, rural, and indigenous households (Tables 1 and 2). Sweet bread and French rolls were the largest contributors to total fortified wheat flour equivalents, far more important than wheat flour per se and sliced bread. Mean values were larger than median values, reflecting skewedness in the values.

A high proportion of households purchased pasta (69%) and rice (79%) in the previous 15 d, and proportions did not differ appreciably among socioeconomic and ethnic groups and residence (Table 1). Median per capita purchases of pasta were ~15 g/d, and were lowest in extremely poor households (Table 2). Median per capita purchases of rice were 24 g/d and were also lowest in extremely poor households. Overall, a high proportion of households across all socioeconomic groups and residences purchased rice and pasta in the previous 12 mo.

Eight percent of households purchased corn flour in the previous 15 d (Table 1). Per capita purchases of corn flour were low [6 g/(person · d)] and varied among different socioeconomic groups, residence types, and ethnicities (Table 2).

We examined iron and folic acid amounts contributed by fortification per adult equivalent unit, as well as the estimated contribution to the daily EAR and RDA for adult menstruating women, by demographic characteristics (**Table 3**). Fortification provided median values of 2.3 mg of iron and 90 μg of folic acid per day per adult equivalent unit. Assuming a low level of bioavailability (5%), the fortification program provided ~12% of the EAR and 5% of the RDA for iron among women from nonpoor communities, and <3% of EAR and RDA values among women of poor and extremely poor communities. At intermediate levels of bioavailability (10%), the contribution of iron from fortification doubled but the contribution of fortification was still 5% or less of the EAR and RDA values for iron among rural and indigenous women. Overall, fortification contributed 6% of the EAR for iron assuming poor bioavailability and 11% assuming intermediate bioavailability; corresponding values for the percentage of RDA levels met were 2% for poor and 5% for intermediate bioavailability.

We also examined the potential benefit of wheat flour fortification on folate status (Table 3). The contribution of fortification to the EAR and RDA for folic acid for women was 33 and 26% across all households, respectively. The contribution to EAR and RDA needs was lowest for women in extremely poor households (5 and 4%, respectively) and highest for urban (78 and 62%, respectively) and nonpoor women (71 and 57%, respectively).

Discussion

Using nationally representative data on household food purchases, we estimated the contribution of wheat flour fortification

TABLE 1 Percentage of Guatemalan households purchasing selected foods in the previous 12 mo and 15 d[1]

Demographic characteristics	Households	Wheat flour 12 mo	Wheat flour 15 d	Sweet bread 12 mo	Sweet bread 15 d	French roll 12 mo	French roll 15 d	Sliced bread 12 mo	Sliced bread 15 d	Pasta 12 mo	Pasta 15 d	Rice 12 mo	Rice 15 d	Corn flour[2] 12 mo	Corn flour[2] 15 d
SES	*n*							%							
Extremely poor	11	7	3	91	76	33	23	5	0.3	79	54	84	69	4	2
Poor	35	16	7	95	89	54	45	13	2	88	70	93	81	11	5
Nonpoor	54	27	12	94	90	79	75	46	18	89	71	93	80	25	12
Residence															
Rural	57	16	8	94	87	53	44	17	4	85	68	91	79	13	6
Urban	43	26	11	94	90	82	78	47	19	90	70	93	79	25	11
Ethnicity															
Indigenous	35	18	8	95	87	52	42	15	4	88	70	90	78	10	3
Nonindigenous	65	22	10	93	89	72	68	38	14	87	68	93	80	22	11
Total population	100	21	10	94	88	65	59	30	11	87	69	92	79	18	8

[1] Values are percentages, $n = 7265$.

[2] Corn flour refers only to industrially made flour and does not take into consideration purchased tortillas made with fortified flour. Information in the survey regarding the type of wheat flour used in tortillas that were purchased by households was not available.

TABLE 2 Median and mean purchases per adult equivalent unit in the previous 15 d of selected foods among all households, by socioeconomic status, residence, and ethnicity[1]

Demographic characteristics	Wheat flour	Sweet bread	Sweet bread FWFE[2]	French roll	French roll FWFE[2]	Sliced bread	Sliced bread FWFE[2]	Total FWFE[3]	Pasta	Rice	Corn flour
SES											
Extremely poor	0, <1	9, 16	6, 10	0, 4	0, 3	0, <1	0, <1	7, 14	5, 9	12, 16	0, 1
Poor	0, 2	26, 47	17, 30	0, 21	0, 16	0, <1	0, <1	25, 48	14, 17	22, 26	0, 3
Nonpoor	0, 4	81, 99	52, 65	53, 75	41, 57	0, 2	0, 2	110, 124	18, 24	30, 35	0, 9
Residence											
Rural	0, 3	24, 50	16, 32	0, 23	0, 18	0, <1	0, <1	24, 52	13, 18	24, 28	0, 5
Urban	0, 3	83, 101	54, 66	63, 81	49, 63	0, 3	0, 2	120, 129	16, 22	25, 32	0, 7
Ethnicity											
Indigenous	0, 2	18, 41	12, 27	0, 19	0, 15	0, <1	0, <1	16, 42	15, 19	20, 25	0, 3
Nonindigenous	0, 3	67, 88	44, 57	32, 63	25, 48	0, 2	0, 1	88, 107	15, 20	27, 33	0, 8
Total population	0, 3	42, 72	27, 47	10, 47	8, 36	0, 1	0, <1	50, 84	15, 20	24, 30	0, 6

[1] Values are means, median, $n = 7265$.
[2] Assuming wheat flour comprises 65% the weight of baked sweet bread and 77% the weight of baked French rolls and sliced bread.
[3] Wheat flour + sweet bread FWFE + French roll FWFE + sliced bread FWFE.

to meeting the iron and folate needs of Guatemalan women of reproductive age. Our approach has limitations and strengths and these derive from the nature of the data available from the ENCOVI survey. The key limitation is that the ENCOVI survey lacked direct estimates of individual food consumption. Instead, we estimated consumption using expenditure data that were collected at the household level. We assumed that most foods purchased within households were indeed consumed and not wasted, spoiled, or fed to animals. A further problem is that expenditures were estimated from a single 15-d recall rather than from purchases over a longer period, which would lead to better characterization of household purchasing behavior. Also, we assumed that the intra-household food allocation was fair and thereby allocated according to physiological need. These are important limitations, and our findings should be interpreted with caution. For these reasons, our analysis describes the "potential" contribution of fortification to iron and folic acid needs rather than the "measured" contribution. Although precise measures of daily household consumption of specific foods by categories of individuals (men, women, and children) would be ideal, the paucity of data regarding household food consumption in Guatemala renders our analysis of food purchases useful.

The strengths of our analysis include the use of a nationally representative survey with a large sample size that includes information on sociodemographic characteristics and food purchases. This information allowed us to quantify the consumption of particular foods by various subgroups of the

TABLE 3 Estimated daily iron and folic acid contribution from fortification per adult equivalent unit and percentage meeting the EAR and RDA of adult menstruating women, by demographic characteristics[1,2]

	Nutrient contribution per adult equivalent unit from fortification[3]			Iron bioavailability[4]				Folic acid[5]	
Demographic characteristics	FWFE, *g/d*	Iron, *mg/d*	Folic acid, *μg/d*	5% EAR, 28.2 *mg/d*	10% EAR, 14.1 *mg/d*	5% RDA, 63 *mg/d*	10% RDA, 31.5 *mg/d*	EAR, 188 *μg/d*[6]	RDA, 235 *μg/d*
SES									
Extremely poor, 11%	7 (2,16)	0.3 (0.1, 0.7)	13 (4,29)	0.8 (0.2, 1.7)	1.6 (0.4, 3.4)	0.3 (0.1, 0.8)	0.7 (0.2, 1.5)	4.7 (1.2, 10.2)	3.7 (1, 8.2)
Poor, 35%	25 (9, 69)	1.1 (0.4, 3.1)	45 (16, 124)	2.7 (1, 7.5)	5.4 (1.9, 14.9)	1.2 (0.4, 3.3)	2.4 (0.9, 6.7)	16.3 (5.8, 44.8)	13 (4.7, 35.9)
Nonpoor, 54%	110 (43, 187)	5.0 (1.9, 8.4)	198 (77, 337)	11.9 (4.6, 20.2)	23.8 (9.2, 40.4)	5.3 (2.1, 9)	10.7 (4.1, 18.1)	71.4 (27.7, 121.2)	57.1 (22.1, 97)
Residence									
Rural, 57%	24 (8, 74)	1.1 (0.4, 3.3)	43 (14, 133)	2.6 (0.8, 8)	5.2 (1.7, 16)	1.2 (0.4, 3.6)	2.3 (0.7, 7.2)	15.5 (5, 48.1)	12.4 (4, 38.5)
Urban, 43%	120 (44, 196)	5.4 (2.0, 8.8)	216 (79, 353)	13 (4.8, 21.1)	26 (9.6, 42.3)	5.8 (2.1, 9.5)	11.6 (4.3, 18.9)	78 (28.7, 126.8)	62.4 (22.9, 101.4)
Ethnicity									
Indigenous, 35%	16 (6, 49)	0.7 (0.3, 2.2)	29 (11, 88)	1.8 (0.7, 5.3)	3.5 (1.4, 10.6)	0.8 (0.3, 2.4)	1.6 (0.6, 4.8)	10.5 (4.1, 31.9)	8.4 (3.3, 25.5)
Nonindigenous, 65%	88 (28, 162)	4 (1.3, 7.3)	158 (50, 292)	9.5 (3, 17.5)	18.9 (6,35)	4.2 (1.3, 7.8)	8.5 (2.7, 15.7)	56.8 (18.1, 104.9)	45.5 (14.5, 84)
Total population, 100%	50 (12, 136)	2.3 (0.5, 6.1)	90 (22, 245)	5.5 (1.3, 14.7)	10.9 (2.7, 29.4)	2.4 (0.6, 6.6)	4.9 (1.2, 13.2)	32.8 (8.0, 88.2)	26.3 (6.4, 70.5)

[1] Values are medians (25th and 75th percentiles), $n = 7265$.
[2] Estimated by expressing the nutrient contribution per adult equivalent unit times 0.677, the coefficient of equivalency for women, as a percentage of EAR and RDA levels for women.
[3] Estimated as FWFE times the fortification level of 45 mg/kg of iron from ferrous fumarate and 1.8 mg/kg of folic acid.
[4] Based on 2 levels of iron bioavailability from diets: poor or 5% (probably the case in extremely poor and poor communities) and intermediate or 10% (probably the case in nonpoor communities).
[5] 1 μg folic acid = 1.7 μg dietary folate equivalents.

population. The strengths outweigh the limitations of our approach and the results provide indirect but useful measures of dietary impact that can contribute to policy formulation and program design. In fact, our approach offers a useful model for countries that have national expenditure data but not dietary data, which is not an uncommon situation.

In countries in transition, such as Chile, where compulsory wheat flour fortification programs have proven successful, clearly for folate (6,8) and indirectly for iron (23), the per capita consumption of wheat flour (mainly as bread) is several times greater than median per capita consumption of wheat flour in Guatemala. Chile currently fortifies wheat flour with ferrous sulfate (30 mg iron/kg), folic acid (2.2 mg/kg), thiamin, riboflavin, and niacin (13,33). The per capita consumption of fortified wheat flour (primarily as bread) in Chilean women was estimated to be 219 g/d, yielding an estimated daily intake of 427 μg/d of folic acid (8). For Guatemala, we estimate that women consumed 34 grams per day of fortified wheat flour, which contributed 61 μg of folic acid (nutrient contribution per adult equivalent unit from Table 3 multiplied by 0.677 to convert values to women equivalent units). Estimates of the daily contribution of iron from fortification to the diets of women are 6.6 mg for Chile and 1.6 mg for Guatemala. In addition, the absorption of iron is likely better in the Chilean than the Guatemalan diet due to lower consumption of iron absorption inhibitors. This case illustrates the importance of context in determining the effectiveness of fortification programs.

Venezuela introduced mandatory corn and wheat flour fortification programs, mostly with ferrous fumarate, in 1993 (18). Per capita intakes of corn and wheat flour in 1999 were estimated to be 84 and 104 grams per day, respectively (34). Although consumption of wheat flour in Venezuela was not as great as per capita consumption in Chile, compulsory fortification of corn and wheat flours seems to have restored the iron status of adolescents of low socioeconomic status to levels found in cohorts examined prior to a pronounced economic crisis that altered food consumption patterns. Iron deficiency (serum ferritin $< 12\ \mu$g/L) affected 14.1% of adolescents of low socioeconomic status living in Caracas in 1989–90 before the economic crisis developed fully, reached a level of 36.6% in 1992 at the height of the crisis, and was 15.8% in 1994 after fortification and despite continuation of the crisis. The corresponding values in these cohorts for anemia were 3.6%, 19.0% and 9.3%, respectively. Although other factors might have contributed to this reduction in anemia and iron deficiency in 1994, fortification of wheat and corn flours likely played a key role.

A motivation for this analysis was the paucity of information about the effectiveness of flour fortification. Despite the limitations inherent in using household food purchase data, strong inferences can be made from the results that can be useful to guide policies and programs to combat iron deficiency and prevent NTDs. Fortified wheat flour appears to be an important source of folic acid for nonpoor, urban, and nonindigenous populations. We estimate that fortified wheat flour supplied 71% and 78% of the EAR for folate for nonpoor and urban women, respectively. Given these estimates, it is likely that the contribution of wheat flour fortification to the intake of other B vitamins such as thiamin, riboflavin, and niacin was also important. However, fortification had more limited potential impact on iron intakes, even in the case of urban, nonindigenous and nonpoor households. For example, we estimate that fortification met only 24% and 11% of EAR and RDA levels, respectively in women of nonpoor households at an intermediate level of bioavailability (10%). Given the large burden of anemia in Guatemala, one would have hoped for greater impact. Unfortunately, the level of iron cannot be increased further in wheat flour, and therefore other food vehicles or interventions will be necessary to build on the achievements of the wheat flour fortification program. If pasta and rice were fortified with iron, the situation would improve little because the median consumption of these foods in Guatemala is low (15 to 24 g/d, respectively), particularly considering the levels of iron that can be added to these foods. Pasta and rice may be effective candidates to deliver other nutrients, such as water soluble vitamins, but they are not good vehicles for appreciably increasing iron intakes. However, just because a major biological impact would not be expected, this does not mean that iron should not be added to pasta and rice; it should, and, given the nature of the problem of iron deficiency in Guatemala, it should be added with urgency.

Thus, despite iron fortification with a good bioavailable compound (ferrous fumarate), the consumption of wheat flour in Guatemala is not high enough to expect a major impact on the iron status of women. However, males and school age children may benefit more than women because their needs are half or less, whereas their wheat flour consumption may be similar. Analyses of dietary intake data are required to properly assess differential impact of fortification by sex and age.

Corn is the main staple in Guatemala; people living in poor, rural areas consume a more traditional diet consisting of corn products, both ground as *masa* (dough) in village mills and produced industrially. Currently, industrially produced corn flour is fortified with 30 mg/kg iron from ferrous fumarate (lime-treated, nixtamalized corn flour); however, a large segment of the Guatemalan population does not have access to industrially produced corn flour and consumes corn flour ground as *masa* in village mills (35). Our results indicate that very little corn flour is purchased as such by households; this is likely an underestimate of industrial flour consumption because some households may purchase ready-made tortillas made from industrial flour. The lack of information about the type of flour used in ready-made tortillas, which can be purchased from stores or households in the neighborhood, prevents further analysis of the potential contribution of fortified corn flour. However, we judge the potential contribution to be minor, given that corn flour contains large amounts of phytic acid, which interferes with iron absorption and results in poor iron bioavailability (36). Finally, fortification of corn ground as *masa* in small village mills is not feasible because of the large number of small mills throughout the country.

In conclusion, the flour fortification program of Guatemala is probably making an important contribution to improving folate intakes in all but poor, rural, indigenous households. On the other hand, the potential contribution to the prevention of iron deficiency in women is modest, even for the more privileged groups (nonpoor, urban, and nonindigenous households). This does not mean that the flour fortification program has no value; quite the contrary; the program should be supported and monitored closely to ensure compliance and quality of the fortified products. Also, other vehicles such as pastas and rice should be fortified when feasible, even if the increase to nutrient intakes is not large. Importantly, attention must be given to improving the effectiveness of other programs, such as iron/folic acid supplementation prior to and during pregnancy, and with particular attention to the less-privileged sectors of Guatemalan society.

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