Impact of fortification of flours with iron to reduce the prevalence of anemia and iron deficiency among schoolchildren in Caracas, Venezuela: A follow-up

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Editorial note

Programs of cereal fortification as a means of reducing micronutrient deficiencies, particular of iron and folate, continue to expand to more and more countries, with the strong support of the international and bilateral agencies concerned with nutrition. It is widely accepted that the programs can contribute importantly to decreasing the prevalence of iron deficiency. However, there are almost no acceptable before and after data on the effectiveness of these programs. The 1996 report of the initial results of fortification of wheat and maize flour in Venezuela [1] still stands out as almost the only report of the effectiveness of cereal fortification in improving iron status.

The fortification program in Venezuela was instituted in 1993 in response to a deteriorating economic situation and evidence of a rising prevalence of iron deficiency and anemia. Both anemia and iron deficiency, as judged by serum ferritin, decreased by approximately 50% according to a survey using similar sampling methods in 1994, nearly two years later. However, the prevalence of anemia increased again in the following years, although iron deficiency did not. It was speculated that the continuing deterioration in the economic situation and in the diets of the population was a critical factor. The present paper reviews the results of surveys in 1997, 1998, and 1999 and their significance. It does resolve the paradox of increasing anemia without evidence of deterioration in iron status.

The initial observation of a decrease in anemia and improvement in iron status in Venezuela was possible only because of repeated national nutrition surveys before the fortification program was initiated. There is an urgent need for more good baseline data on iron status before fortification programs are introduced, so that by subsequent surveys the relative effectiveness of iron fortification of cereals can be better understood.

Editor

Reference

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Abstract

In Venezuela, a severe economic crisis starting in 1983 provoked a progressive reduction in the quantity and quality of food consumed by people from the low socioeconomic strata of the population. This situation resulted in a continuous increase in the prevalence of iron deficiency in the 1980s and 1990s. In 1993, an iron-fortification program was started, in which precooked corn and white wheat flours were enriched with iron, vitamin A, thiamine, niacin, and riboflavin. White wheat flour was enriched with the same nutrients, except for vitamin A. In 1996 we published the results of the impact of fortification of precooked corn and white wheat flours on the prevalence of anemia and iron deficiency in the population. A survey carried out in Caracas in 307 children aged 7, 11, and 15 years showed that the prevalence of iron deficiency measured by serum ferritin concentration dropped from 37% in 1992 to 16% in 1994, only one year after the iron-fortification program began. The prevalence of

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anemia, as measured by the hemoglobin concentration, diminished from 19% to 10% during the same period. This article reports the results of three other surveys carried out in 1997, 1998, and 1999 on children of the same age and socioeconomic groups that were evaluated in 1990, 1992, and 1994. There were no significant differences in anemia or iron deficiency among the last three surveys. The prevalence results from the last seven years seem to indicate that, after a dramatic reduction in 1994, iron deficiency tended to stabilize, while the prevalence of anemia increased to the same level found in 1992, before the fortification program started.

Key words: Flour fortification, iron, ferritin, iron deficiency, anemia

Introduction

Iron deficiency affects more than 2 billion people throughout the world and is severe enough to cause anemia in 1 billion people [1, 2]. The causative factor is the poor bioavailability of iron from cereal-based diets, which are the staple food in many developing countries [3]. Strategies for combating iron deficiency include control of parasitic infections, especially hookworm, improvement of sanitation, iron supplementation, and iron fortification [4–6]. Of these strategies, iron fortification of basic foods is the most economical and most convenient approach and has the advantage that it does not require changes in the food habits of the individual [6].

As reported previously, beginning in 1960 a progressive reduction in the prevalence of iron deficiency was observed in Venezuela [6–10]. However, the economic crisis that began in 1983 with currency devaluation led to a progressive reduction in the quality and quantity of the diet consumed by people of low socioeconomic strata, who currently make up 80% of the Venezuelan population. This resulted in a continuous increase in the prevalence of iron deficiency in the 1980s and 1990s. As a result, in 1993 the Venezuelan Government nominated a special commission for the enrichment of food (CENA). A program of iron fortification was started the same year to enrich precooked corn flour with iron, vitamin A, thiamine, niacin, and riboflavin. White wheat flour was enriched with the same nutrients, except for vitamin A (table 1).

TABLE 1. Enrichment of food vehicles in Venezuela

Nutrient	Precooked maize flour	White wheat flour
Vitamin A (IU/kg)	9,500	—
Thiamine (mg/kg)	3.1	1.5
Riboflavin (mg/kg)	2.5	2.0
Niacin (mg/kg)	51.0	20.0
Iron[a] (mg/kg)	50.0	20.0

a. As ferrous fumarate until 1994. Since then, 30 mg/kg as ferrous fumarate and 20 mg/kg as electrolytic iron.

In 1996, we reported the impact of this fortification program on the prevalence of anemia and iron deficiency among children in Caracas during the first two years of the program [11]. The prevalence of anemia, as judged by plasma hemoglobin, decreased from 37% to 15%; the prevalence of iron deficiency, as measured by serum ferritin, decreased from 19% to 10%. This paper describes the results of three surveys carried out in the following three years (1997–99) on children of the same age and socioeconomic group who were sampled in the same manner as in 1990, 1992, and 1994.

Methods

Subjects

Three national surveys were carried out in 1997, 1998, and 1999, which evaluated 4,992 children and adolescents from 1 to 15 years of age. The impact of the fortification program was evaluated by comparing previous published results [11] with data obtained from these three surveys. Only 7-, 11-, and 15-year-old children and adolescents from labor (IV) and low (V) socioeconomic strata of the Caracas population were evaluated. In all six surveys, public schools were selected randomly from the same list, and a random sample of children was drawn. The subjects were classified according to age, sex, and socioeconomic stratum [12]. Those in the two lower strata were selected to give blood samples.

Among other hematological tests, the hemoglobin concentration [13] was measured in all subjects included in the surveys (590 subjects in 1997, 478 in 1998, and 545 in 1999). The serum ferritin concentration [14] was determined in most of the samples (571 samples in 1997, 466 in 1998, and 537 in 1999).

Anemia was defined as a hemoglobin concentration below 115 g/L for 7-year-old children of both sexes, 120 g/L for 11- and 15-year-old females, and 125 and 130 g/L for 11- and 15-year-old males, respectively. The cutoff for iron deficiency was a serum ferritin concentration less than 10 µg/L for 7- and 11-year-old males and females, and less than 12 µg/L for 15-year-old males and females.

Statistical analysis

Statistical analysis of the serum ferritin concentration of samples from the 1997, 1998, and 1999 surveys of the Caracas population [5, 13] was performed by logarithmic procedures. The chi-square test with the Bonferroni correction as a post-test was used to compare the prevalence of iron deficiency and anemia between surveys. Analysis of variance (ANOVA) was used for the comparison of hemoglobin and ferritin concentrations among surveys.

Results

The corn flour industry produces 60 million tons per year, of which 10 million tons of processed corn are transformed into 700,000 tons of corn flour. Wheat is mainly imported from the United States and Canada, and 12 million tons of processed wheat produces 700,000 tons of wheat flour. The cost of the micronutrient mixture added to the flours represents less than 1% of the market selling price and is absorbed by the industry.

From 1993 (when the fortification program started) to 1999, random samples of commercial flour packages were taken approximately every two months from shelves at food stores by trained persons from the National Institute of Hygiene and the National Institute of Nutrition and were analyzed in the laboratory for iron concentration at the consumer level. The analysis of iron content showed that it ranged between 80% and 120% of the expected value.

Changes in the prevalence of anemia and iron deficiency in children and adolescents from the low socioeconomic strata of the Caracas population are shown in table 2. Because the results were essentially the same for children and adolescents and no sex differences in response were observed, the data were pooled for further analysis. There were no significant differences in anemia or iron deficiency among the last three surveys. The prevalence results from the last seven years indicate that, after a dramatic reduction in 1994, iron deficiency, as judged by serum ferritin, tended to stabilize. The prevalence of anemia also diminished dramatically from 1992 to 1994, but for the last three surveys it returned to the value that was reported before the fortification program was started.

The median ferritin concentration during the last seven years had a clear tendency to increase, even though the increase was small for the last three surveys (table 3). This index was significantly increased in 1997, 1998, and 1999 as compared with 1992, when the iron-fortification program had not been started.

Discussion

For an iron-fortification program to be successful, it is important to choose food vehicles that are consumed daily, to select an iron compound that is well absorbed, and to have the ability to control the enrichment. The Venezuelan program of nutrient enrichment met all three criteria. The overall population consumes precooked corn flour bread, and the target low-income population eats wheat flour as either bread or pasta.

The impact of iron fortification on the prevalence of iron deficiency and anemia deserves several comments. In 1992, one year before the iron-fortification program started, iron reserves had decreased to a median of 15 μg/L. After fortification, they increased markedly to 22 μg/L in 1994. This occurred despite the fact that the diet consumed by this population continued to deteriorate due to the severe reduction in quality and quantity of the diet consumed by the labor and lower socioeconomic strata of the population.

As evidence for this, FUNDACREDESA (Foundation for the Study of National Growth and Human Development) calculated the cost of a monthly base diet for a family of five (father, mother, and three children). This diet contains only locally produced foods; the main constituents are corn flour, rice, plantain, potatoes, milk, fruit, meat, vegetables, and eggs. The average macronutrient contents are 2,200 kcal, 65 g of protein, 343 g of carbohydrate, and 66 g of fat. In 1994 the monthly cost of this diet was 989 Bolívares (Bs.), equivalent to US$7. In 1998 the cost increased to 142,000 Bs. (US$259). During this period, 10% of the middle class, 20% of the labor class, and 30% of the low socioeconomic class would not have been able to afford this base diet to meet their nutritional requirements [12, 15].

It has been shown that the absorption of iron from ferrous fumarate is similar to that from ferrous sulfate when these supplements are added to corn or wheat flours [16]. The industrial process of preparing flour permits full control of the fortification ingredients. Ferrous fumarate had been used to fortify flour in Caracas for less than six months before the recommendation was made by the Venezuelan Institute for Scientific Research to use it on a national scale.

During the first year of iron fortification, a problem was observed in two regions of the country where hard water is used for making maize bread in the evening for consumption on the afternoon of the next day. The bread turned slightly dark the day after it was baked; this change was confirmed in the laboratory. Fortunately, the hard water responsible was limited to only two regions. About 22,000 people, less than 1% of the population of Venezuela, were affected. Nevertheless, in response to this problem, the iron-fortification pattern of the maize flour was changed in 1994. The precooked corn flour was enriched with 30 mg/kg of iron as ferrous fumarate and 20 mg of electrolytic iron. This pattern of iron fortification continued from February 1994 to 1998 without any further problem with the fortification.

There are some examples in the literature of the early effects of iron-fortification programs [16, 17]. Garby and Areekul [18] reported the effect of fortification of fish sauce with NaFe-EDTA in a Thai village for one

TABLE 2. Prevalence of anemia and iron deficiency in children and adolescents from the low socioeconomic strata of the Venezuelan population, according to surveys conducted in 1992, 1994, 1997, 1998, and 1999

			Anemia			Iron deficiency		
Year	Age (yr)	Sex	No. evaluated	No. affected	%	No. evaluated	No. affected	%
1992[a]	7	M & F	72	10	13.9	72	26	36.1
	11	M	39	12	30.7	39	10	25.6
	11	F	52	12	23.1	52	26	50.0
	15	M	51	5	9.8	51	16	31.4
	15	F	68	12	17.6	68	27	39.7
	Total[b]		282	51	18.1	282	105	37.2
1994[a]	7	M & F	91	3	3.3	91	1	13.2
	11	M	65	10	15.4	65	8	12.3
	11	F	65	7	10.8	65	5	7.7
	15	M	30	1	3.3	30	1	3.3
	15	F	66	9	13.6	66	24	36.8
	Total[b]		317	30	9.3	317	50	15.8
1997	7	M	64	8	12.5	63	9	14.3
	7	F	72	8	11.1	71	6	8.5
	11	M	98	24	24.5	93	4	4.3
	11	F	85	18	21.2	83	9	10.8
	15	M	115	3	2.6	110	10	9.1
	15	F	156	25	16.0	151	42	27.8
	Total[b]		590	86	14.6	571	80	14.0
1998	7	M	69	4	5.8	64	4	6.3
	7	F	48	5	10.4	47	5	10.6
	11	M	69	26	37.7	66	6	9.1
	11	F	58	6	10.3	58	2	3.4
	15	M	112	16	14.3	112	9	8.0
	15	F	122	32	26.2	119	26	21.8
	Total[b]		478	89	18.6	466	52	11.2
1999	7	M	84	12	14.3	83	18	21.7
	7	F	93	8	8.6	92	17	18.5
	11	M	108	32	29.6	107	4	3.7
	11	F	89	8	9.0	88	11	12.5
	15	M	65	11	16.9	63	8	12.7
	15	F	106	22	20.8	104	25	24.0
	Total[b]		545	93	17.1	537	83	15.5

a. Data from 1992 and 1994 surveys have been previously published [11].
b. Totals are weighted means.
There were no significant differences between years in the prevalence of anemia or iron deficiency.

year. The fortification produced an additional intake of approximately 10 mg of iron per day, and after one year the packed cell volume increased by about 1.5% as compared with the control population. In a trial of iron fortification in three Central America communities, sugar was the food vehicle enriched with NaFe-EDTA; the additional intake provided approximately 3 mg of iron per day. After 20 months they found a significant increase in the serum ferritin concentration in the populations of all three communities [19]. Finally, in a South African iron-fortification trial [20, 21], curry powder was fortified with NaFe-EDTA and tested in an urban Indian community whose daily intake of iron via fortification was 7 mg. After one year, there were significant increases in the hemoglobin concentration to a mean of 15 g/L and in the ferritin concentration to a mean of 15 µg/L.

In summary, in the Venezuelan population, in spite of the economic crisis of the last seven years, the iron-fortification program was sufficient to reduce

TABLE 3. Statistical analysis of ferritin concentration in total samples of children 7, 11, and 15 years of age from the 1992, 1994, 1997, 1998, and 1999 surveys

Survey	Values	Mean	SE	Median	95% confidence interval	*n*
1992	Arithmetic	18.01	0.82	15	16.39–19.64	282
	Geometric	13.46[d]	1.05	15	12.22–14.83	
1994	Arithmetic	25.20	0.86	22	23.51–26.89	317
	Geometric	20.54[c]	1.04	22	18.96–22.25	
1997	Arithmetic	28.67	0.74	24	27.21–30.13	571
	Geometric	21.91[a,b,c]	1.03	24	20.51–23.38	
1998	Arithmetic	33.98	1.03	28	31.50–36.46	466
	Geometric	26.08[a]	1.26	28	24.26–28.02	
1999	Arithmetic	31.64	0.89	27	28.27–31.76	537
	Geometric	24.1[a,b]	1.03	27	21.03–24.30	

Means with no letters in common are significantly different ($p < .001$).

the prevalence of iron deficiency, as judged by serum ferritin, to 16% and to maintain the median ferritin concentration at 27 µg/L.

The prevalence of anemia was reduced during the first two years of fortification, but it returned to prefortification levels for the last three surveys. This could be due to the continuous deterioration of food consumption (even corn flour, the main staple food in Venezuela, showed a drop in sales volume of 10% during 1998–99), the impressive epidemic of dengue affecting Venezuela for the last five years, and other viral infections. C-reactive protein was measured in the 1998 and 1999 surveys. Samples were taken from all subjects with anemia (with or without iron deficiency). In 1998, 89 samples were analyzed, and 3 were positive. In 1999, 6 of 93 samples were positive.

Another factor affecting the prevalence of anemia could be the change in the fortification pattern, which included a proportion of a less available source of iron. In spite of the fact that conditions in the country continue to deteriorate, this fortification program has improved iron stores and prevented the prevalence of anemia from increasing further.

There is still the paradox that anemia is returning despite the improvement in iron stores. We suspect the 37-fold increase in the cost of diets led to other micronutrient deficiencies that increased the prevalence of anemia even though iron deficiency decreased. Unfortunately, we do not have the baseline or current micronutrient data to determine this, but we will next evaluate the current status of other micronutrients in an effort to explain the paradox.

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