

dose of iron ascorbate was made according to previous studies (10).

Preparation and mixing of labeled test material

Enriched sugar. In vitro studies of enriched sugar were carried out by preparing aliquots of 5 g of sugar mixed with 5 mg of iron in the forms of: ferrum reductatum, ferrous sulfate coated, ferrous sulfate uncoated, ferric ammonium citrate, and iron glycerophosphate. Additional aliquots of these iron compounds were also prepared but this time 30 mg of ascorbic acid were added to each one. Each aliquot was kept in plastic tubes closed with screw caps and tested periodically for color and taste. Aliquots were also tested qualitatively for the presence of Fe^{3+} by the method of potassium ferrocyanide and ammonium thiocyanate (11). The results were expressed qualitatively: traces, positive, and strongly positive.

The enriched sugar preparations for iron absorption studies were made by mixing sugar with labeled ferrous salt before the absorption tests. At the time of administration the enriched sugar was either mixed with the foods or given as drink during meals or between meals.

Standard meal

A meal popular in the northern part of South America and Central America was used as a standard meal. It contains: black beans (1.8 mg Fe), rice (0.3 mg Fe), maize or wheat (1.0 mg Fe), and meat (1.2 mg Fe). Details of preparation are given elsewhere (3, 12).

Diets

A diet consumed by low socioeconomic class inhabitants of Los Andes was selected for this study. It represents an average of foods consumed four or five times a week. The basic vegetable food is maize, which is eaten at each meal; milk is usually drunk at breakfast and supper, a small piece of meat is eaten at lunch, and one egg is eaten at supper.

The diet contains 2171 calories, 69 g of proteins, 61 g of fat, and 33 mg of ascorbic acid—14 mg at lunch and 19 mg at supper. The total iron intake is 14.6 mg of non-heme and 1.2 mg of heme iron from meat.

The foods consumed in this diet are similar to that described in a previous publication (12), but the amount of several foods was increased in order to obtain a total caloric intake close to 2,000 calories, which is the average intake for adults in this area. The only exception was the egg which was included in the supper.

Statistical analysis

As in previous studies (3, 4, 10, 12, 13), the mean absorption and standard deviation were calculated from the logarithm of the percentage of absorption and the results were retransformed as antilogarithms to recover the original units. Statistical comparison between two absorption tests was determined in pairs by Student's *t* test (14).

Absorption studies

Labeled iron salt with a labeled food was administered in the morning after an overnight fast. No food or drink was allowed for 3 hr after the administration of radioac-

tive material. Blood was drawn 15 days later to determine hematological characteristics and radioactivity. The subjects were fed again on the 15th day with new tagged material and blood was taken again on the 30th day. A small amount of iron (0.1 mg Fe), in the form of ferric chloride and labeled with either ^{59}Fe or ^{55}Fe , was used as an extrinsic tag to measure the iron absorption from vegetal foods in each meal. The labeled iron salt was mixed with a maize dough during the preparation of each meal. Accordingly, breakfast tagged with ^{59}Fe was administered the first day, lunch labeled with ^{55}Fe the next day. Fifteen days later, after blood collection for radioactive counting, supper labeled with ^{59}Fe was administered. On the 16th day a standard dose of ferrous ascorbate labeled with ^{55}Fe (3 mg Fe) was administered and the absorption was again determined from the increase of radioactivity found on the 30th day. Approximately 0.6 μCi of ^{59}Fe and 2 μCi of ^{55}Fe were used in each test. Duplicate 10-ml blood samples were prepared for radioactive counting by wet ashing and electroplating following the technique of Dern and Hart (15, 16). Radioactivity was measured in a Tri-Carb scintillation counter. Triplicate standards of the labeled material were counted simultaneously with the blood samples. The iron absorption from each labeled material was calculated from the ^{59}Fe and ^{55}Fe activity in the subjects' blood using an estimated blood volume based on sex, weight, and height (17). According to this method the iron absorption is measured from the amount of radioactive iron incorporated into the red blood cells.

Results

In vitro studies

The color and taste of the enriched sugar had changed after 2 months of storage only in the aliquots containing ferric ammonium citrate and iron glycerophosphate; the other aliquots, containing ferrum reductatum, ferrous sulfate coated, and ferrous sulfate uncoated, remained unchanged during 12 months of observation. Trace amounts of Fe^{3+} were detected in the ferrous sulfate uncoated since the beginning of the observation, but this small amount of Fe^{3+} did not increase during the total observation. Ferrous sulfate coated and ferrum reductatum remained free of trivalent iron for 3 months; they then started to reveal it in trace amounts. The aliquots containing 30 mg of ascorbic acid each behaved as follows: the color and taste of the enriched sugar containing ferric salts were changed after 5 months and the other salts remained unchanged. Trivalent iron was not detected in the two ferrous sulfate preparations during the first 5 months of observation but trace amounts were detected in the last 7 months. No reaction was

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several advantages over the other ed that ferrous sulfate added to e ferrous form for a period of at r, by itself, carries practically no sugar mixed with vegetals is the ar is increased more than 50% drink during the ingestion of a sugar was administered with orange juice, Coca-Cola, and and 0.66, which is more than 3 the mean absorption ratio from e that the fortification of sugar eny than the iron fortification lt could be used in developing mic class. This program could s. *Am. J. Clin. Nutr.* 29;

peasants from rural areas of tested for this study. These od health with the exception anemia. For each subject, in ests, hemoglobin concentra- ration (8), and unsaturated also determined (9).

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ferrous sulfate solution was ferrous sulfate with a specific / μg with a given amount of preparation of the reference

zolano de Investigaciones Caracas, Venezuela. World Health Organization

laboratory, Instituto Venezolanas, and Professor of de Venezuela, Caracas. Investigator, Instituto Venezolanas. *Research Techni- Investigaciones Cientifi- gy, Universidad Central istics Department, In-

TABLE 1
Iron absorption from fortified sugar administered with a meal

Identification	Hb, g/ 100 ml	Transferrin saturation (%)	Iron absorption (%)			
			Standard diet + sugar (10 g) + ferrous sulfate (5 mg Fe)			C Iron ascorbate (3 mg Fe) ⁵⁵ Fe
			A FeSO ₄ ⁵⁵ Fe	B vegetal ⁵⁵ Fe	A/B ratio	
<i>A) Sugar enriched with labeled ferrous sulfate mixed with labeled wheat dough</i>						
R. B.	14.2	20	0.4	0.3	1.33	4.1
D. B.	14.9	36	0.9	1.0	0.90	15.0
J. G.	16.3	25	1.5	1.1	1.36	10.6
M. G.	13.1	19	2.4	1.8	1.33	14.0
C. S.	15.7	35	3.1	3.2	0.97	21.0
L. V.	16.0	31	3.2	3.6	0.89	20.3
M. M.	15.1	34	3.4	2.8	1.21	14.6
O. T.	16.0	23	4.1	3.1	1.32	16.6
N. B.	13.3	26	5.8	4.6	1.26	40.5
G. P.	14.7	10	7.1	6.3	1.13	43.7
A. R.	15.5	23	11.4	11.4	1.00	16.9
A. R. M.	13.8	8	23.1	23.3	0.99	68.2
Mean	14.9	24	3.3	3.0	1.13	18.8
SE			1.4	1.4	0.04	1.2
<i>B) Sugar enriched with labeled ferrous sulfate plus 100 mg of ascorbic acid mixed with labeled wheat dough</i>						
R. V.	14.1	27	1.0	1.3	0.77	13.1
O. B.	13.4	30	1.9	1.9	1.00	2.7
D. V.	15.2	23	2.3	2.2	1.05	13.4
M. P.	15.0	29	2.8	3.5	0.80	36.4
J. C.	13.5	27	4.0	3.9	1.03	27.4
S. M.	14.8	25	4.4	5.3	0.83	25.8
A. M. V.	12.5	28	4.6	5.2	0.88	14.6
O. P.	14.7	26	5.5	5.8	0.95	19.3
E. P.	14.9	25	8.9	10.3	0.86	18.6
L. H.	15.5	40	9.0	8.2	1.10	24.2
E. S.	14.4	20	10.0	8.9	1.12	14.2
O. V.	14.6	15	15.8	15.6	1.01	74.6
D. P.	12.7	7	22.3	21.5	1.04	69.9
Mean	14.3	25	5.1	5.4	0.96	20.5
SE			1.3	1.3	0.03	1.3
<i>C) Sugar enriched with labeled ferrous sulfate administered as a drink in the middle of a meal including intrinsically labeled wheat</i>						
A. S.	14.3	31	1.4	1.3	1.08	
J. J. V.	14.8	28	1.4	1.0	1.40	
E. H.	10.6	27	1.7	1.6	1.06	
N. H.	13.3	16	2.8	1.7	1.65	
J. M.	14.0	24	3.0	1.6	1.88	
C. L.	14.2	17	5.2	2.0	2.60	
A. J. C.	10.0	47	9.5	5.6	1.70	
L. S.	12.5	24	15.3	7.1	2.15	
J. S.	14.4	13	16.6	7.9	2.10	
O. B.	10.6	48	19.7	15.8	1.25	
F. H.	8.3	35	19.8	16.4	1.21	
Mean	12.5	29	5.5	3.5	1.58	
SE			1.4	1.3	0.9	

TABLE 1 (continued)

Identification	Hb
<i>D) Sugar enriched with labeled black beans</i>	
P. A.	11
N. G.	11
Y. B.	11
J. G. L.	11
C. A.	11
F. A. D.	11
E. R. C.	11
M. M. R.	11
G. B.	11
F. M.	10
Mean	15
SE	

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*Iron absorption from fo
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TABLE 1 (continued)

Iron absorption (%)		C Iron ascorbate (3 mg Fe) ⁵⁵ Fe
+ sugar ferrous sulfate (Fe)	A/B ratio	
3	1.33	4.1
0	0.90	15.0
1	1.36	10.6
8	1.33	14.0
2	0.97	21.0
6	0.89	20.3
8	1.21	14.6
1	1.32	16.6
6	1.26	40.5
3	1.13	43.7
4	1.00	16.9
3	0.99	68.2
0	1.13	18.8
4	0.04	1.2

Iron absorption (%)		C Iron ascorbate (3 mg Fe) ⁵⁵ Fe
Standard diet + sugar (10 g) + ferrous sulfate (5 mg Fe)	A/B ratio	
3	0.77	13.1
9	1.00	2.7
2	1.05	13.4
5	0.80	36.4
9	1.03	27.4
3	0.83	25.8
2	0.88	14.6
8	0.95	19.3
3	0.86	18.6
2	1.10	24.2
9	1.12	14.2
6	1.01	74.6
5	1.04	69.9
4	0.96	20.5
3	0.03	1.3

Iron absorption (%)		C Iron ascorbate (3 mg Fe) ⁵⁵ Fe
Standard diet + sugar (10 g) + ferrous sulfate (5 mg Fe)	A/B ratio	
3	1.08	
0	1.40	
5	1.06	
7	1.65	
5	1.88	
0	2.60	
5	1.70	
9	2.15	
3	2.10	
8	1.25	
4	1.21	
5	1.58	
0	0.9	

Identification	Hb. g/ 100 ml	Transferrin saturation (%)	Iron absorption (%)			C Iron ascorbate (3 mg Fe) ⁵⁵ Fe
			A FeSO ₄ ⁵⁹ Fe	B vegetal ⁵⁵ Fe	A/B ratio	
<i>D) Sugar enriched with labeled ferrous sulfate administered as a drink in the middle of a meal including intrinsically labeled black beans</i>						
P. A.	16.6	31	0.9	0.5	1.8	2.7
N. G.	14.8	25	1.1	0.9	1.2	11.0
Y. B.	13.5	19	1.3	1.0	1.2	52.0
J. G. L.	17.9	44	2.6	1.9	1.4	15.3
C. A.	14.8	11	5.1	4.0	1.3	81.2
F. A. D.	15.4	25	5.4	4.4	1.2	14.0
E. R. C.	12.9	19	9.2	2.9	3.2	61.8
M. M. R.	15.0	19	9.6	7.9	1.2	30.5
G. B.	13.6	24	9.8	6.4	1.5	30.9
F. M.	16.2	25	25.7	7.9	3.3	31.9
Mean	15.1	24	4.3	2.7	1.49	23.4
SE			1.4	1.4	0.17	1.4

observed with ferrum reductatum during the same period.

Iron absorption from fortified sugar administered with a meal

Table 1 shows the effect of a standard meal on the absorption of both extrinsic and intrinsic iron. These studies were made to find out whether the absorption of inorganic iron incorporated into the sugar is affected by the absorption-inhibiting substances present in the vegetables in the same proportion as is the native vegetal iron. In experiments A and B, in which iron fortification was mixed with wheat dough and then cooked and administered with the meal, the mean absorption ratio of extrinsic to intrinsic iron was close to one. The addition of 100 mg of ascorbic acid in experiment B increased the absorption but the ratio remained the same. In experiment C, in which the enriched sugar is administered during the meal as a drink, the results indicated that iron fortification absorption was increased about 60% more than that of the native food iron. Similar results were also found when enriched sugar was administered as a drink in the middle of the standard meal in which black beans had been biosynthetically labeled with ⁵⁵Fe.

Iron absorption from fortified sugar administered with beverages

Table 2 shows the absorption of 5 mg of iron as ferrous sulfate mixed with sugar and added to different beverages. The amount of intrinsic iron in these beverages is rather small, less than 0.5 mg/dose. According to the absorption of a reference dose of ferrous salt administered alone, each of the beverages tested inhibits to a certain extent the absorption of iron fortification. Thus, the mean iron absorption from Coca-Cola, Pepsi-Cola, and orange juice is more than 10%; from coffee it is about 7%, and its absorption is further reduced when coffee is administered with milk.

Table 3 shows the absorption of 3 mg of iron from enriched sugar added to beverages and administered in several conditions. The absorptions from Coca-Cola and from coffee are very similar to those observed in Table 2; absorption from them increases when the enriched sugar also contains 50 mg of ascorbic acid, and it is markedly reduced when it is administered with the standard meal.

The absorption-inhibiting effect of sugar is practically null. The absorption of iron from enriched sugar given alone was 32%, and the mean absorption ratio of fortified sugar to the

TABLE 2
Iron absorption from fortified sugar administered with beverages

Identification	Hb. g/ 100 ml	Transferrin saturation (%)	Iron absorption (%)				
			Sugar + orange juice	Sugar + Coca- Cola	Sugar + coffee	Sugar + coffee with milk	Sugar + Pepsi- Cola
<i>A) Sugar (10 g) enriched with labeled ferrous sulfate (5 mg Fe) added to beverages</i>							
F. M.	14.5	28	1.8	2.3	1.2		16.2
J. C. V.	13.9	38	2.4	1.9	2.2		5.3
E. G.	12.5	18	3.4	8.0	6.3		32.1
R. N.	13.3	29	5.2	9.5	3.4		9.6
J. C. D.	12.9	19	6.9	14.3	4.2		22.1
G. S.	12.5	17	9.2	8.7	5.4		10.8
M. E. G.	11.9	22	10.4	17.4	6.0		37.8
N. R.	14.5	38	13.3	25.6	18.4		33.8
A. V.	14.5	23	29.8	20.3	15.7		25.3
Y. M.	14.7	38	31.7	19.3	6.0		24.5
Y. G.	12.2	19	45.8	35.0	17.6		53.0
E. R. C.	13.7	24	79.0	56.7	60.1		97.2
Mean	13.4	26	10.7	12.5	7.0		23.3
SE			1.4	1.3	1.3		1.2
<i>B) Sugar (10 g) enriched with labeled ferrous sulfate (5 mg Fe) added to either Pepsi-Cola or coffee with milk</i>							
J. M.	13.1	31			0.6	17.6	22.9
R. C.	13.8	47			1.0	4.4	10.3
P. S.	15.3	39			2.4	5.6	13.3
E. R.	14.5	33			2.9	35.4	61.5
D. R.	13.7	18			4.1	32.6	50.7
C. A.	14.3	16			3.9	30.6	39.5
R. V.	15.3	25			7.6	15.9	17.4
A. G.	13.5	18			12.5	11.2	15.8
M. L.	13.3	30			5.5	29.6	34.7
E. P.	13.3	30			9.6	28.4	32.6
R. B.	10.7	12			25.8	33.9	57.3
Mean	13.7	27			4.3	18.3	27.5
SE					1.4	1.3	1.2

reference dose of iron ascorbate from the seven subjects tested was 0.92.

The results shown in Tables 2 and 3 can be compared with more accuracy when the results are calibrated according to the absorption of the reference dose of iron ascorbate which has been tested in each study. This is calculated by multiplying the absolute mean absorption from each test by the ratio between the composite mean absorption from the reference dose of all individuals and the mean absorption from the reference dose for the given study (Table 4). The absorption ratio of enriched sugar administered with beverages to the reference dose of iron ascorbate showed some unexpected results. In the

case of fortified sugar given with orange juice, the absorption ratio was lower (0.45) than that observed when with Coca-Cola and Pepsi-Cola, which were 0.54 and 0.66, respectively. This difference in absorption is not due to ascorbic acid content, since the orange juice used contained 60 mg/100 ml and the other two beverages contained about 0.5 mg/100 ml. Fortified sugar administered with Coca-Cola did not exhibit a marked absorption increase when the sugar was enriched with 50 mg of ascorbic acid, but its absorption was markedly reduced when it was administered with a standard meal containing several vegetables. The absorption of fortified sugar administered with coffee was increased

TABLE 3
Iron absorption from enriched

Identification	Hb. g/100 ml
<i>A) Sugar (5 g) enriched with la</i>	
C. R.	14.7
R. V.	14.3
C. R.	13.6
F. B.	13.9
M. D. M.	13.4
L. C.	14.7
T. S.	16.1
D. A. M.	16.4
R. P.	14.0
E. C.	14.3
C. R. V.	13.4
R. C.	10.8
R. G.	11.7
F. P.	16.8
S. H.	13.8
D. S.	16.4
L. S.	11.2
M. R. M.	12.6
Mean	14.0
SE	
<i>B) Sugar (5 g) enriched with labe</i>	
N. J. R.	16.0
J. B.	14.5
R. P.	12.7
O. T.	13.3
M. E. L.	12.0
M. D.	15.4
N. B.	13.3
M. C.	13.4
C. V.	12.2
Mean	13.6
SE	
<i>C) Sugar (5 g) containing labeled Fe during the intake of a standard meal</i>	
E. H.	12.2
R. G.	11.2
M. T.	14.3
C. S.	13.8
F. B.	7.0
M. J. C.	11.5
J. I. C.	12.7
T. T.	11.3
F. H.	9.2
F. B.	8.5
Mean	11.2
SE	

TABLE 3
Iron absorption from enriched sugar administered with beverages

Absorption (%)		
Sugar + coffee with milk	Sugar + Pepsi-Cola	Iron ascorbate
<i>Oranges</i>		
		16.2
		5.3
		32.1
		9.6
		22.1
		10.8
		37.8
		33.8
		25.3
		24.5
		53.0
		97.2
		23.3
		1.2
<i>Pepsi-Cola or coffee with milk</i>		
0.6	17.6	22.9
1.0	4.4	10.3
2.4	5.6	13.3
2.9	35.4	61.5
4.1	32.6	50.7
3.9	30.6	39.5
7.6	15.9	17.4
12.5	11.2	15.8
5.5	29.6	34.7
9.6	28.4	32.6
25.8	33.9	57.3
4.3	18.3	27.5
1.4	1.3	1.2

sugar given with orange juice, ratio was lower (0.45) than when with Coca-Cola and Pepsi-Cola were 0.54 and 0.66, respectively. The difference in absorption is not due to the iron content, since the orange juice contained 60 mg/100 ml and the beverages contained about 0.5 mg of iron. The enriched sugar administered with orange juice did not exhibit a marked absorption when the sugar was enriched with iron and ascorbic acid, but its absorption was markedly reduced when it was administered with a standard meal containing iron. The absorption of fortified sugar administered with coffee was increased

Identification	Hb, g/100 ml	Transferrin saturation (%)	Iron absorption (%)			
			Enriched sugar + Coca-Cola ⁵⁵ Fe	Enriched sugar + coffee ⁵⁵ Fe	Enriched sugar only ⁵⁵ Fe	Iron ascorbate (3 mg Fe) ⁵⁵ Fe
<i>A) Sugar (5 g) enriched with labeled ferrous sulfate (3 mg Fe) added to beverages</i>						
C. R.	14.7	27	6.1	3.0		11.1
R. V.	14.3	24	8.3	3.3		10.7
C. R.	13.6	34	10.3	3.8		12.8
F. B.	13.9	34	10.3	4.1		21.6
M. D. M.	13.4	30	12.3	8.2		49.7
L. C.	14.7	34	13.2	13.1		43.1
T. S.	16.1	57	13.9	8.7	37.5	22.5
D. A. M.	16.4	26	14.7	4.2		38.3
R. P.	14.0	31	16.0	1.9	18.0	22.9
E. C.	14.3	18	18.0	11.0		10.8
C. R. V.	13.4	11	19.5	33.9		44.0
R. C.	10.8	5	21.3	15.3		30.7
R. G.	11.7	16	21.6	7.7	28.7	30.1
F. P.	16.8	47	28.6	1.5	20.3	19.7
S. H.	13.8	25	32.9	14.5	37.4	37.4
D. S.	16.4	17	47.3	10.4	42.7	71.4
L. S.	11.2	5	48.8	27.6	49.9	67.3
M. R. M.	12.6	9	68.9	40.8		85.2
Mean	14.0	25	18.6	7.9	31.6	28.8
SE			1.2	1.3	1.2	1.2
<i>B) Sugar (5 g) enriched with labeled ferrous sulfate (3 mg Fe) and ascorbic acid (50 mg) added to each beverage</i>						
N. J. R.	16.0	18	11.5	4.8		76.8
J. B.	14.5	42	20.6	49.3		34.5
R. P.	12.7	41	25.5	26.6		48.7
O. T.	13.3	22	44.7	24.1		67.8
M. E. L.	12.0	20	52.2	19.4		54.0
M. D.	15.4	40	54.6	37.2		50.8
N. B.	13.3	14	61.3	32.7		48.0
M. C.	13.4	13	82.6	70.3		89.1
C. V.	12.2	10	78.7	39.0		51.8
Mean	13.6	24	40.7	27.8		55.9
SE			1.2	1.3		1.1
<i>C) Sugar (5 g) containing labeled ferrous sulfate (3 mg Fe) added to each beverage and given to subjects as a drink during the intake of a standard meal (A)</i>						
E. H.	12.2	19	1.2	0.8	1.1	20.2
R. G.	11.2	9	1.9	1.5	2.4	35.5
M. T.	14.3	49	2.2	1.6	12.7	27.2
C. S.	13.8	23	2.5	1.2	1.9	38.2
F. B.	7.0	4	2.6	5.7	7.2	50.0
M. J. C.	11.5	10	4.7	2.8	10.4	62.2
J. I. C.	12.7	17	4.8	7.3	8.7	67.4
T. T.	11.3	16	10.4	6.6	7.0	65.5
F. H.	9.2	4	11.5	4.7	6.6	64.3
F. B.	8.5	6	28.2	10.8	14.4	64.1
Mean	11.2	16	4.4	3.1	5.5	46.0
SE			1.4	1.3	1.3	1.1

TABLE 4
Calibration of the absorption from iron fortification administered with several beverages according to the iron absorption from a reference dose

Beverage	Calibrated iron absorption (%)	
	Beverages	Iron ascorbate ^a
A) Sugar enriched with 5 mg of iron as ferrous sulfate		
Orange juice	14.9	32.5
Coca-Cola	17.4	
Pepsi-Cola	21.6	
Coffee	9.8	
Coffee + milk	5.1	
B) Sugar enriched with 3 mg of iron as ferrous sulfate		
Coca-Cola	21.0	32.5
Coca-Cola + 50 mg of ascorbic acid	23.7	
Coca-Cola + meal	3.1	
Coffee	8.9	
Coffee + 50 mg of ascorbic acid	16.2	
Coffee + meal	2.2	
Sugar only	29.9	
Sugar + meal	3.9	

^a Composite mean absorption of all individuals tested.

about twice when ascorbic acid was added to sugar and was reduced about one-third when it was administered with the standard meal.

Absorption of iron fortification administered with a Venezuelan diet

Table 5 provides the results of non-heme iron absorption from both native food iron and iron fortification in a Venezuelan diet. The data on the percentage of transferrin saturation and the absorption from the reference dose indicate that the numbers of normal and iron-deficient subjects in each study are different. Consequently, calibration of the absolute value of each test was calculated by multiplying it by the ratio of the composite mean absorption from the reference dose of all individuals tested to the mean absorption of the reference dose for the given study (Table 6). Data on iron absorption from Coca-Cola and coffee in experiments A and B of Table 3 were also calibrated. The total daily iron absorption from both the original iron contained in the diets and the iron fortification was also calculated.

The percentage of iron absorption from fortified sugar mixed with the food is practically the same as the non-heme iron absorption from the Andes diet (Table 6). These results are expected, since iron fortification and native vegetable food iron show similar absorption and also because a 2-fold increase of iron intake does not modify significantly the percentage of iron absorption (3). As was observed in the results of Table 1, fortified sugar administered as a drink during meals showed higher absorption than when it was mixed with the vegetables of a meal. A further increase in absorption was found when fortified sugar contained ascorbic acid in a proportion of 1 mg of iron/17 mg of ascorbic acid. The only exception was the absorption at supper. It is possible that one egg eaten with this meal besides the vegetables prevents the enhancement of absorption. Finally, the absorption of fortified sugar administered with Coca-Cola and coffee between meals was 3 times and 2 times higher, respectively, than the same amount of iron fortification administered with the meals.

The total daily non-heme iron intake in the Andes diet was 14.6 mg and its total absorption was 0.47 (Fig. 1). An additional 0.41 mg of iron absorption was obtained when 10 g of enriched sugar containing 5 mg of iron were mixed with vegetables in each meal. However, if the 15 mg of iron fortification is distributed in aliquots of 3 mg of iron fortification administered in each meal as a drink, and the other 6 mg of iron fortification is given between meals, one aliquot of 3 mg with Coca-Cola and the other aliquot with coffee, the total iron absorption from the iron fortification administered with the meal is 0.55 and that obtained between meals is 0.90. Thus, the total iron utilization of iron fortification increases thrice with the sole modification that 40% of the iron fortification is administered with beverages between meals.

The total absorption of iron fortification exhibited a further increase to 0.87 g with the meal and to 1.22 mg with the beverages when each aliquot of enriched sugar was administered with ascorbic acid.

Discussion

During the last three decades, wheat flour and farina (18-21) have been used as vehicles

TABLE 5
Non-heme iron absorption from

Identification	Hb. g/l
A) Absorption of non-heme	
A. J. A.	15.1
C. C.	14.7
P. G.	14.5
A. D. C.	13.7
N. B.	14.2
C. C.	12.3
E. L.	14.0
M. T.	11.6
M. V.	12.8
O. C.	14.7
E. L.	13.2
R. L.	15.5
A. E. L.	14.1
R. G.	14.3
Mean	14.0
SE	
B) Absorption of iron fortification mixed with the vegetables	
T. M.	15.3
V. U.	14.4
R. G.	15.1
R. G.	16.0
B. R.	14.0
R. G.	13.6
J. G.	15.3
M. C. G.	13.4
R. M.	15.6
F. G.	13.0
I. G.	13.8
I. A.	12.8
Mean	14.4
SE	
C) Absorption of iron fortification	
A. D.	15.8
S. V.	14.5
A. D. P.	12.5
C. G.	11.9
O. F.	13.4
C. R.	10.1
J. C. T.	16.5
J. A. T.	16.0
C. S.	13.6
M. H.	13.3
R. P.	13.8
C. T. V.	6.0
A. P.	15.3
Mean	13.3
SE	

TABLE 5 (continued)

Identification	Hb, g/100 ml	Transferrin saturation (%)	Iron absorption (%)			
			Breakfast ⁵⁵ Fe	Lunch ⁵⁵ Fe	Supper ⁵⁵ Fe	Iron ascorbate ⁵⁵ Fe
<i>D) Absorption of iron fortification by sugar (5 g) enriched with labeled ferrous sulfate (3 mg Fe) plus ascorbic acid (50 mg) given in each meal as a drink</i>						
C. G.	15.8	34	1.7	1.1	0.8	10.9
R. S.	15.6	15	4.5	7.7	4.5	20.9
M. G.	15.1	58	5.2	5.4	2.3	5.0
C. S.	13.1	22	5.4	9.1	1.2	9.5
E. V.	11.9	19	5.7	7.0	6.3	66.6
R. U.	15.4	34	6.0	8.5	2.4	22.2
J. R. U.	15.6	66	6.7	11.5	15.2	75.5
M. P.	7.9	14	15.8	23.9	4.9	64.0
J. D. B.	15.6	34	16.7	23.8	1.5	22.4
E. B.	10.0	4	22.8	18.2	15.8	65.3
A. V.	13.2	11	23.2	14.0	18.1	76.9
C. P.	11.6	10	23.3	26.2	14.8	31.1
A. J. V.	11.9	10	33.5	35.5	35.3	76.1
J. M. G.	14.7	12	39.5	23.7	28.7	62.1
Mean	13.4	25	10.6	11.7	6.0	32.2
SD			1.3	1.3	1.4	1.3

for iron fortification. The studies of Elwood et al. (1, 2) on the absorption of iron fortified with wheat flour, as well as those recently carried out by the extrinsic tag method (3), have demonstrated that this vehicle contains absorption-inhibiting substances that reduce considerably the absorption of iron fortification. Other vegetables, such as maize, also provoke marked reduction of iron fortification (3, 22, 23). Milk and eggs also carry absorption-inhibiting substances that decrease the iron absorption to the levels found when they are administered with vegetables (4, 5, 23, 24). Starch or sucrose does not reduce the absorption of inorganic iron in rats (25). The fortification of common salt was recently reported; this vehicle, fortified with 0.1% of iron as ferric orthophosphate, 1.25% of ascorbic acid, and 2.5% of starch, does not show discoloration. The authors recommend this fortified salt in countries where rice or maize forms the staple food (26).

The studies presented here demonstrate that sugar has some advantages over the other vehicles used in the past. In vitro studies demonstrated that ferrous sulfate added to sugar is maintained in the ferrous form for a period of at least 1 year, and it does not induce adverse changes in the vehicle, such as

taste and color, that could prevent the commercial use of the article.

Sugar by itself carries practically no inhibiting substances that could affect the iron absorption. Sugar is used in the diets mixed with vegetables such as wheat, beans, and maize. In such instances, sugar has no advantage over other vehicles previously used, the absorption of iron fortification being the same as of the native food iron (Table 1). However, the absorption from enriched sugar is increased more than 40% over that observed in native vegetal iron when it is administered as a drink during the ingestion of a meal. Sugar is also ingested with drinks between meals. In such instances, the absorption of iron from fortified sugar is only affected by inhibiting substances present in the beverage. The absorption studies from enriched sugar added to Coca-Cola, Pepsi-Cola, orange juice, coffee, or coffee with milk showed that the mean absorption ratio of each beverage to iron ascorbate absorption was between 0.45 and 0.66 in the first three beverages and was reduced to 0.30 in coffee and to 0.15 in coffee with milk. The amount of ascorbic acid contained in Coca-Cola and Pepsi-Cola tested is too meager (0.5 mg/100 ml) to account for their enhancing effect on

TABLE 6
Calibration of the non-heme
and from iron fortification

Source of iron
A) Diet alone
B) Fortified sugar mixed food
C) Fortified sugar given drink
D) Fortified sugar containing mg of ascorbic acid given as a drink
E) Fortified sugar given with Coca-Cola with coffee
F) Fortified sugar containing mg of ascorbic acid given with Coca-Cola with coffee

^a The calibration of non-heme

iron absorption. The 0 affected by fortified sugar changes rapidly to black tated and poorly absorbed communication at Inter Hematology, Jerusalem.

In the Andes diet the fortified sugar mixed with locally the same as non-heme from the diet. The same sugar, but administered between meals, increases the iron by a factor of 3, an increase when fortified sugar with ascorbic acid (Fig. 1). All these data provide advantages of using sugar fortification, especially in for their subsistence on vegetables which foods such as beef not paramount, to induce of non-heme iron. A vehicle for iron fortification recommended because of increasing its intake, this is the only one that can be absorption-inhibiting effect foods. It would be useful in countries where beverages are

TABLE 6
Calibration of the non-heme iron absorption from native food iron
and from iron fortification in Andes diet

Absorption (%)	
Supper ⁵⁵ Fe	Iron ascorbate ⁵⁵ Fe
(3 mg Fe) plus ascorbic acid (50	
0.8	10.9
4.5	20.9
2.3	5.0
1.2	9.5
6.3	66.6
2.4	22.2
15.2	75.5
4.9	64.0
1.5	22.4
15.8	65.3
18.1	76.9
14.8	31.1
35.3	76.1
28.7	62.1
6.0	32.2
1.4	1.3

Source of iron	% iron absorption (calibrated) ^a				Composite mean absorption of reference dose of all subjects
	Breakfast	Lunch	Supper	Between meals	
A) Diet alone	3.6	4.1	2.4		33.3
B) Fortified sugar mixed with food	3.5	2.3	2.5		
C) Fortified sugar given as a drink	7.6	5.7	6.1		
D) Fortified sugar containing 50 mg of ascorbic acid and given as a drink	11.0	12.1	6.1		
E) Fortified sugar given with Coca-Cola				17.4	
with coffee				10.8	
F) Fortified sugar containing 50 mg of ascorbic acid and given with Coca-Cola				24.2	
with coffee				16.5	

^a The calibration of non-heme iron absorption was made according to the iron absorption of the reference dose (12).

at could prevent the com-
article.

carries practically no inhib-
that could affect the iron
is used in the diets mixed
such as wheat, beans, and
stances, sugar has no advan-
vehicles previously used, the
n fortification being the
native food iron (Table 1).
orption from enriched sugar
than 40% over that ob-
vegetal iron when it is
drink during the ingestion
is also ingested with drinks
such instances, the absorp-
m fortified sugar is only
ating substances present in
e absorption studies from
dded to Coca-Cola, Pepsi-
coffee, or coffee with milk
mean absorption ratio of
iron ascorbate absorption
and 0.66 in the first three
s reduced to 0.30 in coffee
ffee with milk. The amount
contained in Coca-Cola and
is too meager (0.5 mg/100
or their enhancing effect on

iron absorption. The only beverage so far
affected by fortified sugar is tea; its color
changes rapidly to black, and iron is precipi-
tated and poorly absorbed (T. H. Bothwell,
communication at International Congress of
Hematology, Jerusalem, 1974).

In the Andes diet the iron absorption from
fortified sugar mixed with the food is practi-
cally the same as non-heme iron absorption
from the diet. The same amount of fortified
sugar, but administered with the meal and be-
tween meals, increases the total iron absorp-
tion by a factor of 3, and there is a further
increase when fortified sugar is also enriched
with ascorbic acid (Fig. 1).

All these data provide evidence of the
advantages of using sugar as a vehicle for iron
fortification, especially in populations relying
for their subsistence on vegetable foods and in
which foods such as beef, fish, or fruits are
not paramount, to induce adequate absorp-
tion of non-heme iron. Although sugar as a
vehicle for iron fortification may not be
recommended because of the risk involved in
increasing its intake, this vehicle is appar-
ently the only one that can avoid in part the
absorption-inhibiting effect of vegetable
foods. It would be useful in developing coun-
tries where beverages are highly consumed

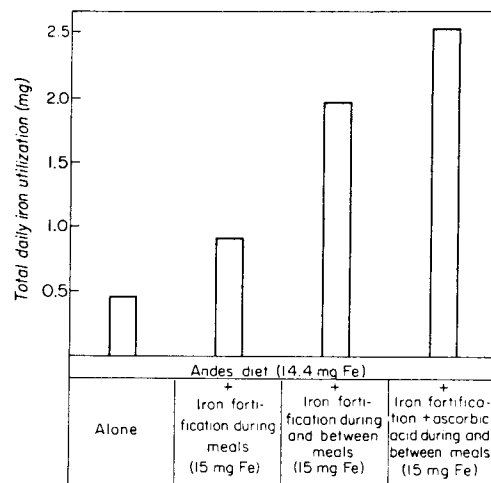



FIG. 1. Total daily non-heme iron utilization from both fortified sugar and native food iron in Andes diet. The absorption of food iron is increased about twice when iron fortification is administered with the meals, and increased about 4 times when the same amount of iron fortification is administered during and between meals; experimentation showed a further increase when ascorbic acid is added to fortified sugar.

between meals by the low socioeconomic class. Thus, a program of sugar fortification could be extended to all sugar consumption or be restricted to soft drinks. The restriction of fortified sugar to soft drinks will also reduce

the risk of high iron intake in the nonvulnerable parts of the populations. 

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Lactose malabsorption in Mexican-Americans

Catherine E. Woteki,¹ P

ABSTRACT
population group (MA) children selected nutritional each child. Glucose lactose load. children, and ethnic group. Allowances were below the calories, nutrients drank more than MA, but no greater incidence. Mexican-American majority of the

Lactose malabsorption in healthy populations throughout the Western hemisphere and mixed heritage populations examined for lactose malabsorption include North and South Americans (2-4), Eskimos (5, 6), Puerto Ricans (7, 8), Jamaican children (9), medical students (10), Creoles in Surinam (11), children and adults (12), and adults (13). The prevalence of lactose malabsorption in these groups ranges from 10% in Oklahoma Indian children (2) to nearly 100% in Indians of Colombia (4).

Mexican-Americans form the largest minority group in the United States in many areas of the South. In this majority ethnic population, lactase activity and lactose malabsorption in Mexican-Americans was examined in a small group of adult men. Lactase concentrations were found to be low in these subjects (13). To date, no studies of lactose malabsorption have been reported in