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# Lessons Learned with Iron Fortification in Central America

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## Introduction

The countries of Central America have been pioneers in the developing world regarding food fortification initiatives. Salt fortification with iodine was introduced since the late 40s and 50s[1]; sugar fortification with vitamin A is carried out in national programs in Guatemala, Honduras, El Salvador, and Nicaragua, beginning in the 70s[2]; and cereal flour fortification with iron and B vitamins was introduced in the 60s. Salt[3] and sugar[4] fortification have been carefully characterized and evaluated, and the impact of these two interventions to prevent and to control iodine[3] and vitamin A deficiency,[4] respectively, is well established. This did not happen with cereal flour fortification, however, and the effect of this intervention is unknown. Nevertheless, some lessons can be extracted from our experience; these will be discussed in this review.

## Evolution of Wheat Flour Fortification in Central America

Central America introduced fortification of wheat flour between the late 1940s and the 1960s, following this practice in the United States and Canada. The levels of micronutrients were aimed to restore the micronutrient content of the wheat seed that are lost during milling. Table 1 lists these levels. In 1992 the Institute of Nutrition of Central America and Panama (INCAP) recognized that iron deficiency anemia (IDA) was still a public health problem in all countries of the region; INCAP launched an initiative to improve the enrichment characteristics of foods. Guatemala passed legislation—still in effect—to raise and to change the iron compound from elemental iron to ferrous sulfate. This suggestion was made following the example of Chile with wheat flour fortification. However, Guatemalan weather and current bakery practices caused green and black spots in breads when ferrous sulfate was first introduced. This condition prompted the return to elemental iron. However, it was mandatory to use iron of small particle size (45 $\mu$m or less), which was expected to attain a slightly inferior effect compared with ferrous sulfate. Central America used reduced iron instead of the desirable electrolytic iron. Folic acid was also introduced at this time; Guatemala and El Salvador were among the first countries to recognize the importance of this nutrient in food fortification. However, the selected level was for restoration purposes, and hence, it is lower than the current level used in other countries that introduced this practice later. In order to enhance the bioavailability of iron, calcium (a reported competitor of the mineral absorption mechanisms) was eliminated as a fortificant of wheat flour.

In the second half of the 1990s, the policies of economic globalization started to influence the interchange of products and services in the Central American region. It became necessary to harmonize technical requirements of food fortification programs in order to ensure the food fortification programs survive under such conditions. Thus, INCAP launched "new" fortification recommendations for wheat flour to be applied simultaneously in all countries. According to the new recommendations, a higher level of folic acid was suggested (Table 1) and ferrous fumarate was selected as the iron source. Now, all Central American countries, with the exception of Guatemala, are fortifying wheat flour with the proper level of folic acid. Guatemala still uses the specification of 1993. Presently, the countries are discussing the adoption of INCAP's recommendations. It is important to point out that in some countries of Central America, fortification changes have been ahead of modifications in the corresponding legislation.

## Fortification of Nixtamalized Corn Flour in Central America

Tortilla made with lime-treated, also referred to as nixtamalized, corn flour (NCF) is the main staple of the countries of northern Central America. Therefore, the industrially produced NCF is potentially a good vehicle to bring micronutrient to consumers. Fortification of this food started as a decision of this industry in the 1970s. However, the biologic impact, if any, should have been small because at that time only a very small portion of the population was consuming industrially produced flour. Fortification levels were similar to those of wheat

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**Table 1.** Evolution of Wheat Flour Fortification in Central America. Micronutrient Content (mg/kg)

| Nutrient | 1948–1960* | 1993–** | INCAP's Proposal (2001)§ |
|---|---|---|---|
| Iron | 28.7–36.6 | 55–65 | 55¶ |
| Thiamin | 4.4–5.5 | 4.0–6.0 | 6.2 |
| Riboflavin | 2.6–3.3 | 2.5–3.5 | 4.2 |
| Niacin | 35.2–44.0 | 35–40 | 55 |
| Folic acid | — | 0.35–0.45 | 1.8 |
| Calcium | 1100–1375 | — | — |

* Guatemalan Technical Norm, COGUANOR NGO-34090.
** Guatemalan Governmental Decree 498-93.
§ Minimum levels, which include the intrinsic content of the unfortified flour.
¶ From which 45 mg/kg using ferrous fumarate. In the previous years was reduced iron.

**Table 2.** Fortification of Nixtamalized Corn Flour in Central America. Micronutrient Content (mg/kg)

| Nutrient | Guatemala (Tortiya, 1970s) | Costa Rica (Maseca, 1999)* | INCAP's Proposal (2001)§ |
|---|---|---|---|
| Iron | 30.9 (elemental) | 22.0 (ferrous bisglycinate) | 54 (ferrous fumarate)¶ |
| Thiamin | 4.8 | 4.0 | 6.1 |
| Riboflavin | 2.8 | 2.5 | 2.5 |
| Niacin | 35.3 | 45.0 | 49.0 |
| Folic acid | — | 1.3 | 1.0 |

* Governmental decree of Costa Rica No. 28086-S, 1999.
§ Minimum levels.
¶ From which 25 mg/kg using ferrous fumarate.

flour (Table 2). Recently Costa Rica passed legislation to fortify NCF following the suggested levels of micronutrients for wheat flour but requesting 22 mg/kg iron from ferrous bisglycinate. This decision was made based on the supposedly better bioavailability of this compound over others. The company Maseca supported and adopted this decision as a means to improve public appeal for its product. The company introduced fortified NCF in all Central American countries, independent of any government motivation. They soon found, however, that the color of the flour changed; this was why it was only used in products destined for supermarkets rather than for industrial use (i.e., tortilla producers). The latter use is the most important from an epidemiologic point of view. This case illustrates that nowadays, neighboring countries easily adopt a fortification practice used in one country, and it is prompted for economic interest rather than a public health initiative. Similar to the case of wheat flour, INCAP proposed a "new" fortification profile, which has the advantage of using the same micronutrient premix but in different proportions. The objective is to reduce cost and to improve availability and price for the use of the same product.

**Table 3.** Fortification of Composite Flours in Guatemala. Micronutrient Content (mg/kg)

| Nutrient | Incaparina [Corn flour (60%) Cotton-seed flour (40%)] | Bienestarina [Corn flour (70%) Soybean flour (30%)] |
|---|---|---|
| Iron (ferrous fumarate)* | 112–180 | 200 |
| Thiamin | 17 | 11–22 |
| Riboflavin | 10 | 12–20 |
| Niacin | 136 | 142–205 |
| Folic acid | 3.3§ | 3.3§ |
| Vitamin $B_{12}$ | 0.002§ | 0.002§ |
| Zinc | 1.2§ | 1.2§ |
| Vitamin A | 12.0–13.5 | 13.5–15.0 |
| | 4.5§ | 4.5§ |

* In the past was reduced iron.
§ Proposed.

## Fortification of Composite Flours in Guatemala

One of the most important products developed by INCAP in the 1960s was a series of composite flours made with corn and other ingredients while looking for the complementary amino acid composition for corn protein. The most famous product is INCAPARINA, which has been in the Guatemalan market for almost 20 years.[5] Incaparina is made with corn and cottonseed flours. Other similar products, replacing the cottonseed flour with soy flour, were simultaneously designed and evaluated, but they were not commercially introduced until the 1990s. All of these products are enriched with micronutrients in amounts approximately fours times the amount in wheat and corn flours (Table 3). Iron type was initially elemental, but it has been recently changed to ferrous fumarate. This example shows that these products accept large contents of iron without sensorial limitations as in the case of simple cereal flours, and therefore the composite flours should be considered as good candidates to bring important amounts of iron and other micronutrients to populations at risk. Nevertheless, in this case the improvement of iron status owing to the consumption of iron-fortified flours was not determined either.

## Recent Efforts to Improve Iron Supply through Fortification

In spite of all efforts in food fortification with iron, the Central American population is still suffering from IDA.[6] There are many reasons to explain this situation, including of course that the implemented fortification

**Table 4.** Technologic Compatibility of Iron Compounds as Fortificants of Wheat Flour in Central America*

| Compound (assayed range) | Characteristic (similar to fortified control with 60 mg Fe/kg, reduced iron) | | | |
|---|---|---|---|---|
| | Color | Peroxide Formation | Dough Viscosity | Specific Volume of Bread |
| Ferrous fumarate (30–60 mg Fe/kg) | 30–60 | 30–60 | 30–60 | 30–60 |
| Ferrous bisglycinate (15–30 mg Fe/kg) | 15–30 | 15–30 | 15–30 | 15–22.5 |
| NaFeEDTA (15–30 mg Fe/kg) | 15–30 | 15–30 | — | — |
| Ferrous sulfate (30–60 mg Fe/kg) | 30–60 | — | — | — |

* Unpublished data. M. Alvarado, licentiate thesis, Universidad de San Carlos de Guatemala, and the Institute of Nutrition of Central America and Panama (INCAP/PAHO).

programs have been unsuccessful. It is obvious that large sectors of the population are not consuming sufficient amounts of the fortified foods, but it might also be that the bioavailability of iron in those foods is low. The latter subject has received little attention until recently. The process of iron fortification was introduced without a system to check for its efficacy and effectiveness. This situation might be also common in other countries.

In view of the situation, during the last 3 years, INCAP initiated a series of studies aimed to optimize the fortification programs. The technologic compatibility of different iron compounds was analyzed. The study included the evaluation of ferrous sulfate, ferrous fumarate, ferrous bisglycinate, and NaFeEDTA. These compounds have been reported in the literature as having good bioavailability when used as food fortificants. The idea was to determine the maximum load of iron that these foods could tolerate without producing undesirable sensorial changes.

In wheat flour, it was found that both ferrous sulfate and NaFeEDTA—or EDTA alone—could not be used because dough viscosity and specific volume of bread were severely affected (Table 4). Ferrous fumarate behaved adequately at concentrations of up to 60 mg/kg and ferrous bisglycinate behaved acceptably at concentrations of up to 22.5 mg/kg.

Similar work in corn nixtamalized flour suggested that only ferrous fumarate added up to 30 mg Fe/kg did not change the color, odor, and flavor of the tortilla (Table 5). Recent work indicated that 15 mg Fe/kg as ferrous bisglycinate and 15 mg Fe/kg as NaFeEDTA may be also compatible with NCF, but these results need further confirmation under different climatic conditions.

Based on the technologic compatibility, estimated bioavailability, and relative cost, it was concluded that the most suitable iron compound to fortify wheat and corn nixtamalized flours, under the conditions in Central America, is ferrous fumarate. INCAP's recommendations to fortify wheat flour (Table 2) and nixtamalized corn flour (Table 3) are based on these analyses. However, there is still a need to evaluate the biologic efficacy of the fortified flours with ferrous fumarate. It is almost certain that the consumption of products made with fortified flours will help to alleviate iron deficiency, but this alone probably will not have a measurable impact because of the low consumption of wheat flour by the population, or the consistently low distribution and use of nixtamalized corn flour that is produced industrially. A field efficacy trial of these products might be adequate only if the daily consumption were at least 200 g, which is not the case for wheat flour. These circumstances emphasize the need to fortify other foods with iron and/or to introduce other complementary strategies aimed to prevent IDA.

**Table 5.** Technologic Compatibility of Iron Compounds as Fortificants of Nixtamalized Corn Flour in Central America*

| Compound§ (assayed range) | Characteristic (similar to control of tortillas made with unfortified flour) | | |
|---|---|---|---|
| | Odor | Flavor | Color |
| Ferrous fumarate (22–30 mg Fe/kg) | 22–30 | 22–30 | 22–30 |
| Ferrous bisglycinate (22–30 mg Fe/kg) | 22–30 | 22 | — |
| NaFeEDTA (22–30 mg Fe/kg) | 22–30 | 22 | — |

* Unpublished data. C.L. de Pereda, Unit of Food Technology, Institute of Nutrition of Central America and Panama (INCAP/PAHO).

§ Experiments did not include ferrous sulfate, because from experience this compound causes undesirable changes in nixtamalized-corn flour.

It is important to point out that both flours, once they are fortified, become excellent sources of B vitamins, including folic acid, in a proportion more important than iron itself (Table 6). The importance of these fortified flours in the improvement of the vitamin status needs to be evaluated as well.

In summary, in Central America, unlike other food fortification programs with iodine and vitamin A, it is difficult to place all confidence in food fortification of a few commodities to solve the problem of IDA.

**Table 6.** Potential Micronutrient Supply through Fortified Flours in Central America

| Nutrient | Wheat Flour (mg/kg) | Nixtamalized Corn Flour (mg/kg) | RNI* (mg/day) | Percent of Supply§ | |
|---|---|---|---|---|---|
| | | | | Wheat Flour (50 g) | NCF (250 g) |
| Iron | 55 | 54 | 33 | 8.0 | 41.0 |
| Thiamin | 6.2 | 6.1 | 1.2 | 25.8 | 127.1 |
| Riboflavin | 4.2 | 2.5 | 1.3 | 16.1 | 48.1 |
| Niacin | 55 | 49 | 16 | 17.2 | 76.6 |
| Folic acid | 1.8 | 1.0 | 0.4 | 22.5 | 62.5 |

* Recommended Nutritional Intake taken as reference for the family.

§ These estimations should be reduced by the proportion of the micronutrient that is lost during preparation of the foods. For example, 25% thiamin, 7.5% riboflavin, 2.5% niacin, and 20% folic acid.

## Conclusion

Central America has had experience in iron fortification. However, most of this experience has been in the technologic feasibility and theoretic estimations of effects, as well as the application of the fortification process by the industry. There is a need to carry out efficacy field trails of potentially efficacious interventions, as well as to introduce permanent monitoring systems to follow the evolution of IDA in response to the several strategies that are being introduced.

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