Iron Fortification: Country Level Experiences and Lessons Learned[1,2,3]

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ABSTRACT Iron fortification has been used to enhance iron intake in many developed countries for more than 50 years, but only in the last decade has this strategy been applied on a large scale to other parts of the world. Iron fortification of rice is being instituted in the Philippines. Initially, the rice will be produced in government-controlled rice mills and sold at low cost mainly to low income families. Efforts to improve the technology (using coating or extrusion techniques) are currently underway to reduce cost and minimize losses during storage and washing. Effectiveness and feasibility studies are required to test the new technologies and processing/distribution systems. In Venezuela in 1993, the government instituted a mandatory program of iron fortification to enrich precooked corn flour followed by the voluntary fortification of wheat flour. Surveys in school children subsequently showed a sharp drop in iron deficiency. Fortification of fish sauce in Vietnam has shown promising initial results in reducing anemia among anemic, nonpregnant female factory workers. Iron-fortified soy sauce has been shown to reduce anemia in initial studies in children in China, and a large-scale efficacy trial is now underway. These examples indicate that iron fortification of staple foods and condiments holds great promise for the prevention of iron deficiency. J. Nutr. 132: 856S–858S, 2002.

KEY WORDS: • *iron fortification* • *country-level experience* • *iron deficiency anemia*

Iron fortification of staple foods and condiments holds promise as a major intervention to deliver iron in an absorbable form to large populations on a permanent and self-sustaining basis. For over 50 years, many developing countries have been using fortified milled cereals. However, it is only over the past decade that the concept has been applied on a large scale in other parts of the world (in the Middle East, and in parts of Africa and Asia), where iron deficiency anemia is a serious problem and where milled cereals form a major component of the diet. Some Latin American countries, in which iron-enriched flour has been consumed for more than a decade, have demonstrated the viability of food fortification as an effective development strategy. Overall, there is better understanding of the opportunities as well as the challenges in expanding and sustaining food fortification, but progress is at best patchy and slow. Unfortunately, several key issues on advancing fortification policy are still not being addressed.

Although iron has potential for use in more food vehicles than iodine or vitamin A, fortification with iron is technically more difficult because iron reacts with several food ingredients. In the case of iodine and vitamin A, the problem is more of stability of the added compound under different storage and cooking conditions. The biggest challenge with iron is to identify a form that is adequately absorbed and yet does not alter the appearance or taste of the food vehicle. In addition to the general fortification criteria, iron fortification must take into account certain specific considerations such as the distribution of iron across meals, storage under hot and humid conditions and segregation during mixing and storage.

Against the widely held view that iron fortification of food has not been proven efficacious, selected and relatively recent country experiences of diverse scope and reach with iron fortification of staple foods and condiments were presented at the Atlanta conference. The expectation was that success stories from Venezuela, China, Vietnam and the Philippines would inspire agencies and governments to launch ambitious and effective national food fortification programs designed with these success determining factors as well as pitfalls in mind. The speakers highlighted country-level experiences and lessons learned at several levels—spanning the spectrum from efficacy and effectiveness trials to large-scale fortification programs that have led to measurable effect.

Each country's experience highlighted the key milestones in the national development or history of iron fortification of food, followed by summary results of the biological effect derived from the fortified food, and closed with lessons learned and future steps.

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[3] Based on presentations by Dr. Rodolfo Florentino, Philippine Association of Nutrition, Philippines; Dr. Maria Nieves Garcia-Casal, Instituto Venezolano de Investigaciones, Ministerio de Sanidad y Asistencia Social, Venezuela; Dr. Junshi Chen, Chinese Academy of Preventive Medicine, People's Republic of China; and Dr. Nguyen Cong Khan, National Institute of Nutrition, Vietnam.

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Rice fortification in the Philippines

Dr. Rodolfo F. Florentino, outlined efforts by the Food and Nutrition Research Institute in the Philippines since the 1980s to develop a coating technology for the fortification of rice with iron. The revised technology involves the coating of ordinary rice with an alcoholic solution of ferrous sulfate and a suitable coating mixture to produce a premix, which is then mixed with ordinary rice at 1:199 dilution to produce iron fortified rice. An effectiveness study of the coated rice among school children showed an increase in hemoglobin after 6 mo of feeding, but large iron losses during washing and cooking (**Fig. 1**; Joven et al., unpublished data, National Center for Disease Prevention and Control). Subsequently, different iron compounds and solvents were tested to improve color and cost. On the basis of these studies, the National Food Authority developed a program to distribute fortified rice in two provinces as part of a school breakfast feeding program (1999). A food fortification law passed in 2000 calls for mandatory fortification of several foods (including rice) within 4 y. The plan is to initially produce iron fortified rice in government controlled rice mills that sell rice at low cost mainly to low income families. Efforts to improve the technology (using coating or extrusion techniques) are currently underway to reduce cost and minimize losses during storage and washing. Rice fortification also has to address issues of logistics of fortification in several mills spread across the country. Suitable mixers and feeders are required that are designed for different capacities. Effectiveness and feasibility studies must be carried out on the new technologies and processing/distribution systems.

Iron fortification of flours in Venezuela

Dr. María Nieves García-Casal traced the development of the program in Venezuela and its effect as measured through studies of students from Caracas. To address the deteriorating nutritional status of the Venezuelan population after an economic crisis, the government instituted a mandatory program of iron fortification in 1993 to enrich precooked corn flour with 50 mg/kg of iron as ferrous fumarate, vitamin A, thiamine, niacin and riboflavin. Eight months later, fortification of wheat flour was started voluntarily including the same nutrients except vitamin A. The optimal iron fortificant was determined to be a mix of ferrous fumarate and electrolytic iron.

Monitoring of surveys in Caracas in school children age 7 to 15 y showed that the prevalence of iron deficiency (ID) measured by serum ferritin concentration dropped from 37% in 1992 to 16% in 1994 only 1 y after the iron fortification program was started (**Table 1**). Prevalence of anemia, measured by hemoglobin concentration, diminished from 19 to 10% in the same period. Results from three other surveys carried out in 1997, 1998 and 1999 on the same age and socioeconomic groups that had been evaluated in 1990, 1992 and 1994 showed that after a dramatic reduction in 1994, there were no further reductions in either biochemical indicator. It is possible that factors such as viral infections, reduction in corn flour consumption along with an increase in wheat flour intake (with no vitamin A fortification), continuous deterioration of life quality and changes in the iron compound, could be responsible for the return of anemia prevalence to the baseline values found in 1992. Finally, despite deteriorating conditions in the country, it may be concluded that this fortification program has improved and maintained iron stores. The next steps include continuous monitoring of the fortification program, continued research on highly available iron compounds, inclusion of other nutrients such as folic acid and fortification of food items for infants because they do not benefit significantly from currently fortified flours.

TABLE 1

Prevalence of anemia and iron deficiency in children and adolescents aged 7, 11 and 15 y from Caracas

Year	Anemia (%)	Iron deficiency (%)
1992	19	37
1994	9	16
1997	16	13
1998	18	10
1999	17	16

Fish sauce fortification in Vietnam

Dr. Nguyen Cong Khan summarized work on fortification of fish sauce with iron. Vietnam is planning to use food fortification as a major intervention, which aims at providing roughly 30% of the micronutrient requirements of the population by 2010. Fish sauce is a good vehicle for iron fortification programs because >80% of the population consume it regularly. There is a network of fish sauce factories under the supervision of the Ministry of Fishery. Iron fortification of fish sauce can take place before bottling the product with only minor modifications to the production process. The cost of fortifying fish sauce has been estimated to be US$ 0.02/L. A randomized, double-blind efficacy trial in 17 to 49-y-old anemic, nonpregnant female factory workers demonstrated that regular consumption of fish sauce fortified with 100 mg iron as NaFeEDTA per 100 mL fish sauce significantly improved iron

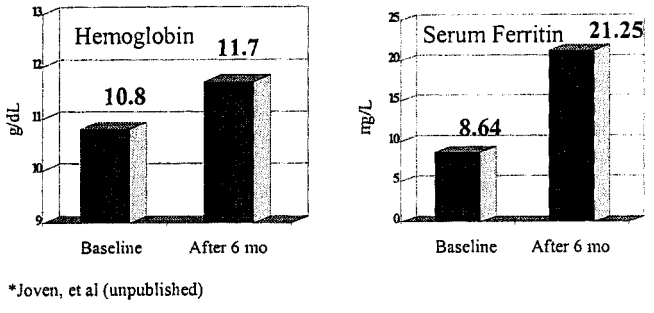

FIGURE 1 Effectiveness of iron-coated rice among Philippino school children. Hemoglobin and serum ferretin levels of anemic subjects (<13 μg/L serum ferritin) at baseline and 6 mo later.

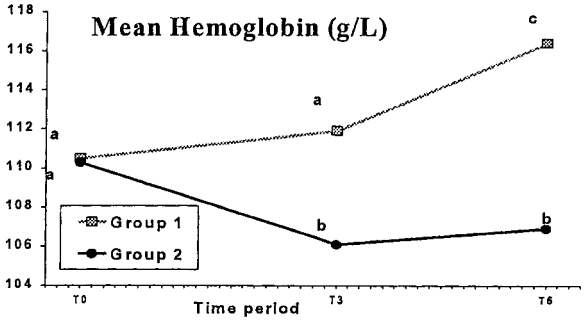

FIGURE 2 Mean hemoglobin concentration after 6 mo consumption of iron-fortified fish sauce.

status and decreased the prevalence of anemia and ID after a 6-mo intervention (**Fig. 2**). The women were served a meal based on noodles or rice, 6 d/wk under strict supervision, with 10 mL fish sauce containing either 10 mg of iron as NaFeEDTA (Group 1) or no added iron (Group 2). Iron status was evaluated at baseline (T0), after 110 d (T3) and after 200 d (T6). As can be seen in the figure, after 3 mo of supplementation, hemoglobin levels increased slightly in Group 1, whereas hemoglobin levels decreased significantly in Group 2. Between T3 and T6, hemoglobin levels increased significantly only in Group 1. Future activities will include an effectiveness study on iron-fortified fish sauce, development of regulations and standards for the control of NaFeEDTA fortified fish sauce, development of communication tools and the organization of an advocacy committee for fortified fish sauce. The Vietnamese government plans to gradually increase the number of fish sauce facilities manufacturing iron fortified fish sauce. Education programs on food fortification, with special emphasis on iron fortification, will also be launched.

Iron-fortified soy sauce in China

Dr. Junshi Chen outlined the steps leading to the identification of soy sauce as a food carrier and the series of studies in progress to establish the feasibility, efficacy and effectiveness of soy sauce fortification. Soy sauce was selected as the food carrier because ~70% of the population in China consumes soy sauce, and NaFeEDTA was selected as the iron compound, because of its high bioavailability for people consuming a plant based diet. (The average rate of iron absorption of NaFeEDTA and $FeSO_4$ in soy sauce in adult Chinese women was found to be 10.5 and 4.7%, respectively.) Soy sauce containing 5 or 20 mg Fe, as NaFeEDTA, was highly effective in the treatment of anemic children within 3 mo. A double-blind, controlled effectiveness trial was started in September 2000, covering ~10,000 subjects in a high-risk population with ~30% prevalence of anemia using NaFeEDTA fortified soy sauce [4 mg/(adult · d)] in half of the subjects (**Fig. 3**). The intervention group consumed the yellow labeled sauce, and the control group the green labeled sauce. As can be seen in Figure 3, after 6 mo, there was a highly significant increase in blood hemoglobin level and a reduction in anemia prevalence rate for all age groups in the intervention group receiving the iron fortified yellow labeled sauce. However, no obvious changes were observed in the control group receiving the unfortified green labeled sauce. The trial will continue for 2 y. In addition to blood hemoglobin level, other variables measured in the study included the following: blood hematocrit, ferritin, zinc protoporphyrin and retinal, anthropometry and food consumption (using a food-frequency questionnaire). The next steps are to provide advice to the national regulatory authorities to promulgate regulations and standards for the control of NaFeEDTA fortified soy sauce and to work with the National Soy Sauce Association to develop mechanisms of gradually expanding the production of NaFeEDTA-fortified soy sauce.

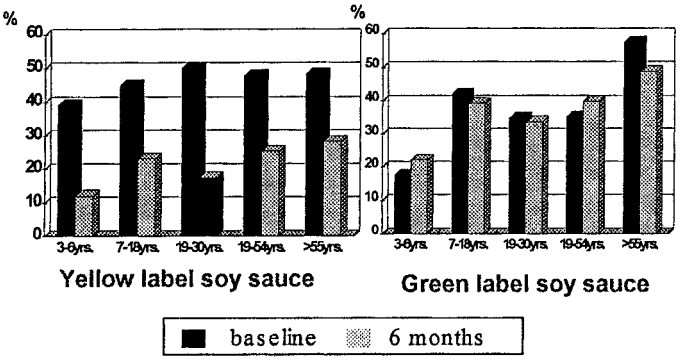

FIGURE 3 Changes in anemia prevalence (%) in Chinese women after 6 mo of intervention. *Left panel* is yellow-labeled soy sauce and *right panel* is placebo (green-labeled sauce).

Summary and recommendations

The presentations underscored the fact that fortification programs are evolving endeavors that require monitoring and constant improvement. The Venezuelan and Philippine experiences correspond to national programs. The Chinese experience with fortified soy sauce, derived from a large scale, ongoing efficacy trial, and the Vietnamese fish sauce results based on a smaller efficacy study, represent promising intervention modes that are still in a developmental stage.

However, all of these experiences should help accelerate the implementation of effective large-scale iron fortification programs. They underscore the fact that when a carefully selected food vehicle and a relatively bioavailable iron compound are combined and consumed by at-risk groups under supervised or normal market conditions, there can be a measurable and important improvement in iron status associated with the introduction of the fortified foods.