Update on Iron Fortification of Milled Cereals

About 30 years ago Bob Loewe and I wrote an article for *Baker's Digest* on iron fortification of flour. We noted then that the choice of which form of iron to use was always a compromise between avoiding detrimental effects on color and shelf-life, maximizing bioavailability (the ability of the body to absorb the added iron), and minimizing cost. At the time elemental iron powder was the most commonly used type of iron, followed by ferrous sulfate, whose use was limited to bakery flour and semolina for pasta. Only a few countries fortified flour: the United States, Canada, the United Kingdom, Chile, and Sweden.

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The biggest change over the last 30 years has been the increase in the number of countries that fortify flour. There are now 52 countries that have iron fortification standards and fortify some or all of their wheat flour. Nine of these countries specify ferrous sulfate, nine specify electrolytic iron powder, one specifies ferrous fumarate, and 33 have no regulation on the type of iron to be added, which usually results in the use of elemental iron powders (either hydrogen-reduced or atomized iron) because they are the cheapest and least reactive forms available.

There are a dozen or so countries that are close to starting flour fortification programs that include iron. The Flour Fortification Initiative estimates that approximately 20% of the white, roller-milled flour produced in the world is currently fortified with at least iron and folic acid. Their goal is to see 70% of this flour fortified by the end of 2008. This will require launching national fortification programs in most of the large wheat-eating countries, including China, Turkey, Egypt, Ukraine, and Russia.

Iron deficiency, and the anemia that results from it, is a major public health problem in the developing world. Some 2 billion people are estimated to suffer from it (4). Iron deficiency reduces the work capacity and productivity of those affected. It is especially dangerous in pregnant women and children. In pregnant women, it increases the risk of premature and low birth weight babies and heightens a woman's risk of death during childbirth. Children with iron-deficiency anemia suffer from poor growth and physical development, impaired cognitive abilities, and reduced resistance to disease. Iron deficiency affects a country's economic status, both through lower worker productivity and higher healthcare costs associated with childhood illnesses and maternal deaths.

Developing Iron Fortification Programs

The most widespread methods employed for the prevention of iron-deficiency anemia are the distribution of iron supplements and the fortification of foods; wheat flour and maize meal are the main food staples used for this purpose. Many flour fortification programs were established primarily to add more iron to the diet, recognizing the tremendous benefits that could result with any degree of effectiveness by reducing the high incidence and heavy burden of iron-deficiency anemia.

Much work has been done over the last 30 years to assess the bioavailability of different types of iron compounds in cereal fortification and find ways of increasing bioavailability to make iron fortification more effective. Many early studies (1) conducted during the 1970s and 1980s were done on behalf of the U.S. Food and Drug Administration (FDA), which was attempting to better specify suitable iron compounds for use in fortification. The results of these studies were never conclusive enough to make any changes in U.S. regulations. The FDA did increase the level of iron to be added to flour in 1982 in response to a petition from the Millers National Federation and the American Bakers Association, which requested, but did not get, an even higher level. Canada eventually followed the United States, requiring the higher level of 44 ppm iron added to harmonize the fortification standards between the two countries. Interest in this area dropped for a decade as a result of the low incidence of iron-deficiency anemia found in developed countries. Sweden even decided to stop fortifying flour with iron in 1994 believing it was no longer needed. It has never been established to what degree iron fortification contributed to the reduction in iron deficiency and related health problems in North America.

During the 1990s there was a revival of interest in iron fortification as mills in developing countries started to fortify flour. Countries in Central America, Nigeria, Venezuela, and Indonesia were some of the first to start national programs. South Africa and Central Asian countries followed. Many of these programs were initiated and supported by UNICEF, the Asian Development Bank (ADB), the Micronutrient Initiative (MI), and, more recently, GAIN.

New iron compounds also have been developed and promoted for use in fortification. These include encapsulated ferrous sulfate, sodium iron EDTA, ferrous bisglycinate, and micronized iron pyrophosphate. Their much higher cost compared with traditional sources has prevented their use in flour despite evidence of their greater bioavailability; however, they have found acceptance in specialty foods for which cost is less of a constraint.

Iron Fortification Recommendations

After a 1996 MI-sponsored conference in Oman, the World Health Organization Eastern Mediterranean Region Office (WHO/EMRO) began recommending the use of ferrous sulfate at 30 ppm or reduced iron at 60 ppm along with 1.5 ppm folic acid in flour fortification in the Middle East. This recommendation has since been put into practice by a number of countries in the region.

In 1999 SUSTAIN formed a task force of international iron experts to establish guidelines on iron fortification (3). The main recommendation was to use ferrous sulfate or ferrous fumarate where possible, and if elemental iron powder was to be used, the electrolytic form was recommended at twice the level of iron used for iron salts. The recommendation to use electrolytic iron as the preferred form of elemental iron powder has been adopted by new cereal fortification regulations in South Africa, countries in Central Asia, and several other countries.

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There are still questions about the ability of iron fortification of flour to prevent iron-deficiency anemia. Some efficacy studies, which use small, controlled feeding experiments, have been quite positive, while others have not. An effectiveness study looks at improvement in iron status in an entire population, which is much more difficult to accomplish. Such a study in Venezuela showed a positive effect from maize (*arapa*) fortification with ferrous fumarate and reduced iron for the first couple years, but the longer term benefits are uncertain. The low rate of iron-deficiency anemia in Chile compared with surrounding countries has often been cited as proof of the benefits of its long-term flour fortification program, but there may be other causative factors involved. Hopefully, new studies will be conducted in countries that have recently adopted national cereal fortification programs.

Recently, a multidisciplinary task force formed under SUSTAIN reviewed the published experimental evidence related to the properties and bioavailability of elemental iron powders used in flour fortification (2). Five production processes were identified. A collection of commercially produced products made using these different processes were collected and made available to researchers for analysis using a variety of testing procedures. A comparison of the physical properties, screening procedures, and rat and human feeding studies in predicting bioavailability has been submitted for publication. The results confirm previous findings that none of the elemental iron powders match the bioavailability of ferrous sulfate, which remains the preferred source of iron for flour fortification. An iron dissolution in acid test was very useful in predicting the relative bioavailabilities of different elemental iron powders and may prove to be the best way to identify suitable iron powders, rather than method of manufacture and particle size, which have been used in the past.

The main concern with using ferrous sulfate has been its effect in promoting oxidative rancidity in flour, particularly when the flour has a high fat content (normally present in high extraction or high ash flours) and is stored for extended periods at high temperature and humidity. Millers know they are always safe in using elemental iron powders, so they tend to prefer this source. There are nine countries (including Chile, Jordan, and soon Iran), however, where ferrous sulfate is required and routinely used. There does not seem to be much of a problem if the iron level is added at 30 ppm or less and the flour is not kept for extended periods.

NaFeEDTA is a chelated form of iron that has superior absorption properties when used in high phytic acid foods or diets. China has been using NaFeEDTA at 20 ppm added iron in a voluntary program for more than a year under a GAIN-sponsored project. This program followed an efficacy trial conducted among anemic school children in China that showed NaFeEDTA to be superior to ferrous sulfate in reducing the prevalence of iron deficiency and anemia. As part of the same trial, ferrous sulfate at 30 ppm added iron was found to be significantly better than electrolytic iron at 60 ppm added iron. Most wheat flour in China is used in nonyeast fermented products, such as noodles and steamed breads, which have low iron absorption due to the high remaining phytic acid content.

Zambia is considering using NaFeEDTA at a level of 10 ppm added iron in a national maize meal fortification program. Food preparations of maize meal also have high levels of phytic acid that inhibit iron absorption. Electrolytic iron is currently being used to fortify maize meal in South Africa, ferrous bisglycinate in Costa Rica, and ferrous fumarate in Venezuela. The main drawbacks to using NaFeEDTA are its high cost and that it does not show up in the iron spot test, which is the standard method by which a mill can determine if flour has been properly fortified.

Summary

Iron fortification of wheat flour and maize meal has been steadily expanding around the world and is expected to continue to do so. Elemental iron powder continues to be the most common source of iron added, but the use of electrolytic iron, ferrous sulfate, and other more bioavailable iron forms is growing. This should assist in the battle against the global health problem of iron-deficiency anemia.

References

1. Forbes, A. L., Arnaud, M. J., Chichester, C. O., Cook, J. D., Harrison, B. N., et al. Comparison of in vitro, animal, and clinical determinations of iron bioavailability: International Nutritional Anemia Consultative Group Task Force report on iron bioavailability. Am. J. Clin. Nutr. 49:225, 1989.
2. Hurrell, R., Bothwell, T., Cook, J. D., Dary, O., Davidsson, L., et al. The usefulness of elemental iron for cereal flour fortification: A SUSTAIN Task Force report. Nutr. Rev. 60:391, 2002.
3. Ranum, P., Lynch, S., Bothwell, T., Hallberg, L., Hurrell, R., et al. Guidelines for iron fortification of cereal food staples. Published online at www.sustaintech.org/publications/pubm7.pdf. SUSTAIN, Washington, DC, 2001.
4. WHO/UNICEF/UNU. Iron deficiency anemia assessment: Prevention, and control. World Health Organization, Geneva, 2001.