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**Fortification of Condiments with Iron: Overcoming Technical and Practical Barriers**

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Condiments are particularly well-suited vehicles for those parts of the world where the most vulnerable population groups do not universally consume industrially processed staple foods. Condiments are sometimes referred to as "non foods" or as "dietary accessory ingredients." They may be generically described as *compounds that are added to foods during the preparation of meals, or ingested during meals, to enhance the flavor of the food without significantly contributing to caloric intake*.

Some examples of fortified condiments that are organoleptically acceptable and have proven efficacious interventions to prevent iron deficiency and iron deficiency anemia are:

- Common salt (NaCl): encapsulated ferrous fumarate, or ferrous sulphate with stabilizers and enhancers.
- Curry powder, soy sauce, fish sauce (NaFeEDTA).
- Noodle seasoning (ferrous sulphate).
- Sugar (NaFeEDTA or Fe bis-glycine).

Some characteristics associated with condiment utilization make most of them attractive vehicles for iron, such as: wide and frequent consumption in small amounts, addition to multiple foods, and well established commercialization channels and consumer preferences. For the same reasons, condiment fortification should be conceptualized as a complement to culturally and economically acceptable combinations of other food-based, supplementation, and public health measures put together to combat iron deficiency and iron deficiency anemia. Moreover, the same criteria for vehicle selection used for staple foods apply to condiments (centrally processed for quality control, regular consumption in predictable amounts, affordable, stability and bioavailability of the micronutrients added under standard local conditions, little or not risk of toxic micronutrient intake, etc.).

Therefore, the most salient technical challenges encountered during the development of condiment fortification technology have to do with:

- Optimizing the bioavailability of iron (choosing the best iron source for maximum absorption; choosing the best combination of enhancers; minimizing the impact of absorption inhibitors);
- Optimizing the daily iron intake (choosing an affordable and biologically meaningful concentration of iron; adjusting for losses during cooking and storage); and
- Preventing (a) fortificant-vehicle interactions that cause chemical changes (in the case of iron, mainly due to reduction-oxidation reactions triggered by direct contact among iron + humidity + fatty acids), which result in undesirable changes in flavor, color, and odor; or

(b) physical incompatibilities due to particle size and color that result in segregation and unacceptable off-colors, respectively.

The Chinese soy sauce, the Vietnamese and Thai fish sauce, and the Canadian and Indian salt iron fortification examples may illustrate solutions of these technical challenges. In the case of salt, stability and organoleptic challenges have been overcome by encapsulation of the iron compound by increasing the purity of the salt (low magnesium and water content are essential) and by using water-resistant packaging. Particle segregation has been solved by producing agglomerates of premix that match the particle size of each particular salt type. Bioavailability has been optimized by selection of water or acid-soluble iron compounds, by using encapsulants that dissolve completely before exiting the duodenum, and by using the highest yet safe concentration of iron (1000 ppm). This process involved development of encapsulation and particle agglomeration technology for the iodine compound, as well as identification or development of commercially available encapsulated iron compounds, blending and stability trials (University of Ottawa), Bioavailability trials (University of Toronto), efficacy trials (Ghana), and scaling up pilot trials currently under way in Indonesia, Kenya, India, and Nigeria.

The principal practical constraints in iron fortification of condiments are similar in origin and nature to those encountered with cereal flours and other staple foods. A few critical practical constraints and approaches to help solve them are as follows:

- High cost of the technology (price of encapsulated premix or of NaFeEDTA leads to detectable increase in the price the final consumer pays for the final product). The estimated price increases of soy sauce (1.4-6.0%), fish sauce (0.9-5.4%), and DFS (25-30%) due to fortification with iron seem modest. When estimated as absolute income amounts, this increase is minor, given the usually low prices and amounts consumed. The cost of technology is significantly reduced when premixes are produced in large scale.
- Marketing and targeting: marketing adds to the cost of the product and may be complicated when cheaper, unfortified products continue to be available in the market;
- Packaging: the right materials and presentations may not be easily determined. Materials that are impermeable to light and moisture are usually expensive.
- Monitoring: given the multiple producers of the same condiment in many settings monitoring and enforcement (if fortification is obligatory) are expensive and logistically complicated.

To make fortified condiments more affordable, there is a range of options:

- To allow the industry to pass the additional costs to the consumer (including costs for QA/QC, monitoring and evaluation) (private-public dialogue).
- To negotiate a subsidy paid by the urban or richer segments of the population in favor of the rural or poorer segments (social pact)
- To reduce the taxes levied on premix importation
- To produce premix in large volumes (economies of scale)

- To increase consumer awareness about the added value of and benefits derived from the added nutrients.

Therefore, in light of the available information on the fortification of condiments, it may be concluded that:

- Condiment fortification is feasible and it is a desirable complement of other interventions applicable to developing countries; although there are several examples of efficacious fortified condiments (controlled conditions), there is a lack of evidence on the actual effectiveness of fortified condiments or staple foods (uncontrolled, market and field conditions).
- Technical and practical constraints may be overcome through systematic and intensive product development, testing for bioavailability, efficacy, consumer acceptability, and effectiveness).
- Creation of a strong public-private partnership to implement large-scale fortification with appropriate quality assurance, monitoring and evaluation components is necessary for success.