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Food Fortification

TO END MICRONUTRIENT
MALNUTRITION

STATE OF THE ART

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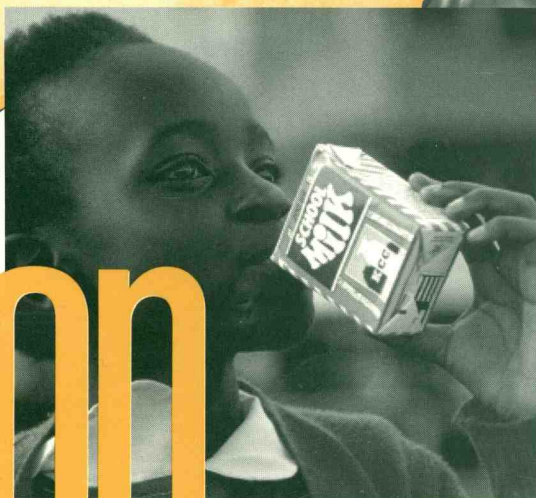
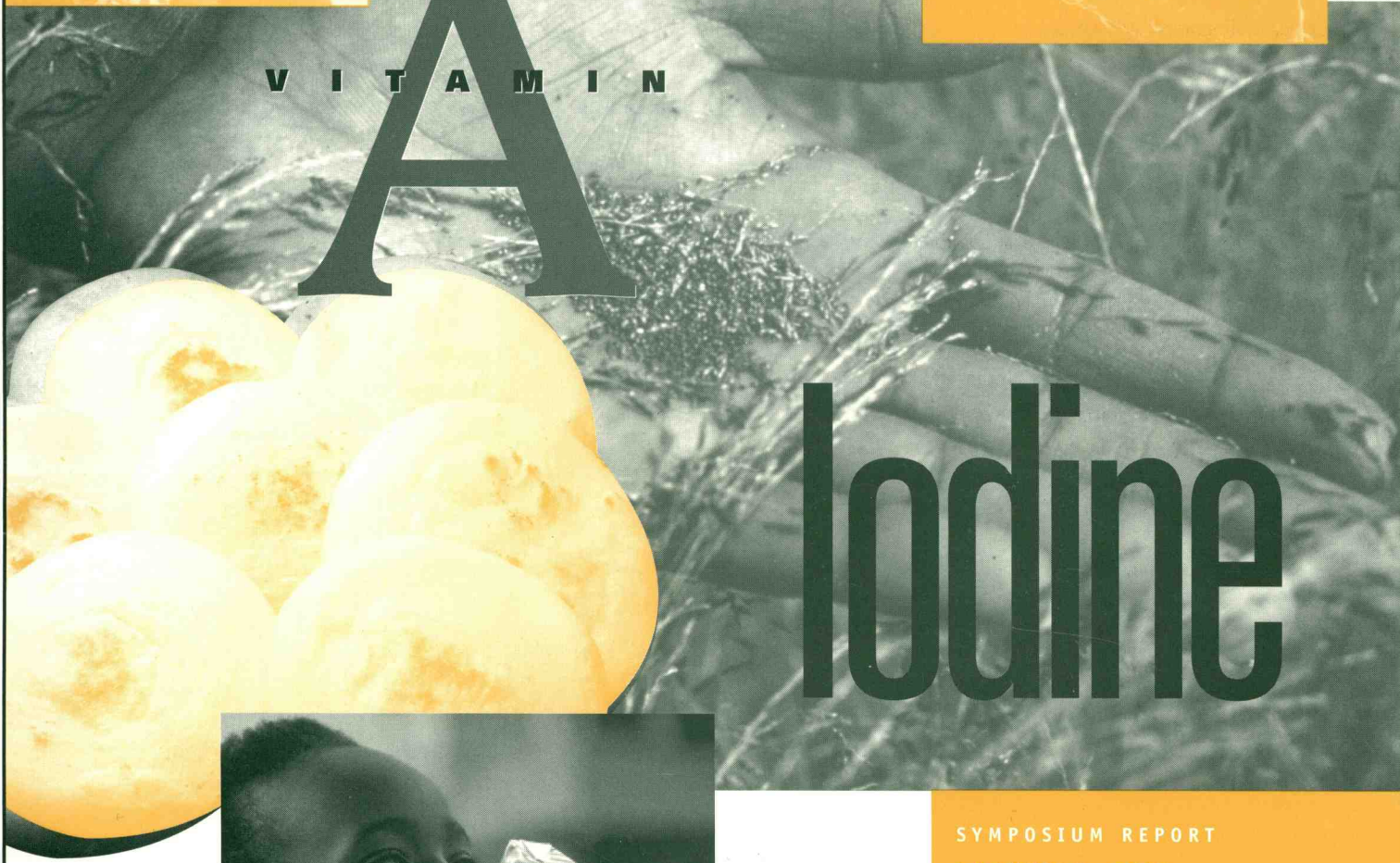
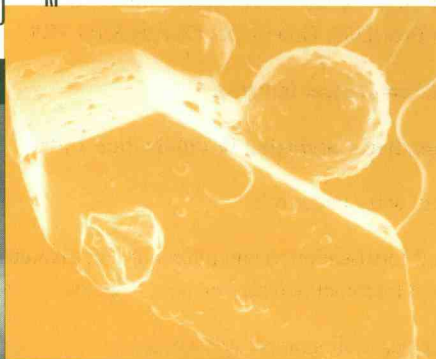
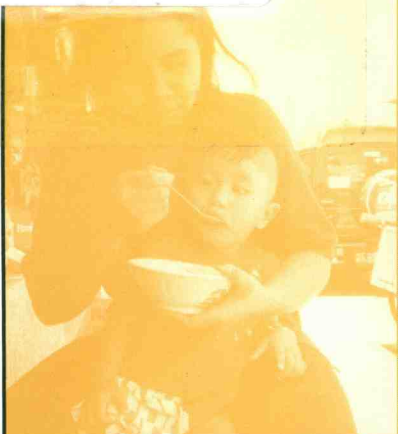
Iodine

SYMPOSIUM REPORT
AUGUST 2, 1997
MONTREAL, CANADA



The
Micronutrient
Initiative
L'initiative
pour les
micronutriments

Iron



Food Fortification to End Micronutrient Malnutrition

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Food Fortification

TO END MICRONUTRIENT MALNUTRITION

STATE OF THE ART

SATELLITE CONFERENCE OF THE XVIth INTERNATIONAL CONGRESS OF NUTRITION

SYMPOSIUM REPORT

AUGUST 2, 1997

HOTEL INTERCONTINENTAL

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Table of Contents

4 Acknowledgments

5 Message from the Sponsors

The Organizing Committee

6 Introduction

The Organizing Committee

15 An Overview

Paul Lachance

Professor and Chairman,
Department of Food Science,
Rutgers University
New Brunswick, New Jersey, USA



Oils, Fats and Margarine

.....

22 Oils, Fats and Margarine: Overview of Technology

Leonard E. Johnson

Scientific Leader, Hoffmann-La Roche Inc., Vitamins Division
Nutley, New Jersey, USA

27 Tackling Micronutrient Malnutrition: Two Case Studies in India

K.K. Sridhar

Vice President, Hindustan Lever, Ltd.
Bangalore, India

32 A Case Report on the Fortification of Margarine with Vitamin A: The Philippine Experience

Florentino S. Solon

President and Executive Director,
Nutrition Center of the Philippines (NCP)
Manila, Philippines



Dairy Products

.....

38 Fortification of Dairy Products with Micronutrients to End Malnutrition

Douglas Bynum

Senior Scientist, Ross Products Division, Abbott Laboratories
Columbus, Ohio, USA

43 Fluid Milk as a Suitable Vehicle for Iron Fortification: The Case of Argentina

Estaban Carmuega

Associate Director,
Center for Studies on Infant Nutrition (CENSI)
Buenos Aires, Argentina

50 Evaluation of a Fortified School Breakfast Program in the Andes of Peru

Enrique R. Jacoby

Associate Director, Institute of Nutritional Investigation,
Lima, Peru

Guillermo López de Romaña

Director, Institute of Nutritional Investigation
Lima, Perú

53 Milk Enhancers and Powdered Beverages

Haile Mehansho

Principle Scientist, Food and Beverage Technology Division,
The Procter and Gamble Company
Cincinnati, Ohio, USA



Milled Grains & Cereal Products

.....

58 Opportunities for Wheat Flour Fortification

Peter Ranum

Micronutrient Assessment Project Director, SUSTAIN
Washington, DC, USA

62 Enrichment of Precooked Corn Flour and Wheat Flour in Venezuela: A Successful Experience

Jose Felix Chavez

Director of Technology, Division of Nutritional Investigation,
National Institute of Nutrition
Caracas, Venezuela

66 The Progress of Wheat Flour Fortification with Vitamin A in the Philippines

Florentino S. Solon

President and Executive Director,
Nutrition Center of the Philippines
Manila, Philippines

72 Triple Fortification: Instant Noodles in Thailand

Visith Chavasit

Senior Scientist, Institute of Nutrition, Mahidol University

Kraisid Tontisirin

Director, Institute of Nutrition, Mahidol University at Salaya
Nakorn Pathom, Thailand

77 Rice Fortification: A Promising Technology

Mahshid Lotfi

Senior Program Specialist, Micronutrient Initiative
Ottawa, Canada

Margaret Dodd Britton

Senior Program Officer,
Program for Appropriate Technology in Health
Seattle, Washington, USA



Condiments

.....

84 Fortification of Food-Flavor Improvers

Omar Dary

Head of Food Analysis and Safety Unit
Institute of Nutrition of Central America and Panama
Guatemala City, Guatemala

89 Double Fortification of Salt With Iron and Iodine

M.G.Venkatesh Mannar

Executive Director, The Micronutrient Initiative
Ottawa, Canada

L.L.Diosady

Professor of Food Engineering
Dept. of Chemical Engineering and Applied Chemistry
University of Toronto
Toronto, Canada

95 Sugar Fortification With Vitamin A: A Central American Contribution to the Developing World

Omar Dary

Head of Food Analysis and Safety Unit
Institute of Nutrition of Central America and Panama
Guatemala City, Guatemala

99 Fortification of Corn Starch in Latin America

Mario Rodenstein

Technical Director,
BestFoods Latin America
Englewood Cliffs, New Jersey, USA

102 Fish Sauce Fortification in Thailand

Sangsom Sinawat

Director of Nutrition, Department of Health
Bangkok, Thailand

106 PARTICIPANTS

112 ABOUT THE SPONSORS

A C K N O W L E D G M E N T S

Food Fortification to End Micronutrient Malnutrition: State of the Art is the result of a unique collaboration of public agencies and private organizations. The forum was sponsored by the Micronutrient Initiative, USAID through the OMNI Project, International Life Sciences Institute, F. Hoffmann LaRoche, Helen Keller International, and the Program Against Micronutrient Malnutrition. The preparation for this conference and these proceedings were coordinated by an organizing committee which included Venkatesh Mannar, Herb Weinstein, Suzie Harris, Alberto Nilson, Susan Burger and Jack Bagriansky.

We would like to extend our deepest appreciation and thanks to the individuals and institutions that helped make *Food Fortification to End Micronutrient Malnutrition: State of the Art* meeting possible:

- Dr. Frances Davidson and Mr. Venkatesh Mannar who insightfully and efficiently chaired the program and, along with Dr. Glen Maberly and Dr. Alex Malaspina, provided the conference with astute and enlightening introductory remarks;
- Seventeen presenters from national governments, private companies, research institutions and non-governmental organizations who came from nine nations to share their knowledge, experience, and insight;
- The International Union of Nutrition Scientists who included the conference as an official Satellite Meeting of their 16th Congress;
- USAID/OMNI, F. Hoffmann-LaRoche, MI, and ILSI for their financial support;
- Nearly two hundred participants from Asia, Africa, Europe, North and South America for their interest and continuing efforts to eliminate the scourge of micronutrient deficiency.

The present publication was finalized by the MI (Jack Bagriansky, Venkatesh Mannar, Mahshid Lotfi and Tanya Guay). The Micronutrient Initiative also provided the financial support for the production and printing of this publication.

MESSAGE FROM THE SPONSORS

The full devastating extent and impact of micronutrient malnutrition have been recognized only recently. Deficits in three key micronutrients – vitamin A, iron and iodine – prevent nearly three billion people from achieving their full potential as students, parents, workers and citizens. Global goals to eliminate micronutrient malnutrition are compelling because the human and socio-economic benefits are vast. Perhaps equally important, these benefits are achievable for a modest investment. The returns are immeasurable.

Fortification of common foods with vitamin A, iodine and iron is one of the most sustainable and cost-effective strategies to deliver key micronutrients to the large populations that desperately need them. In industrialized countries a diversity of food-processing technologies have already played a major role in the substantial reduction and elimination of a number of micronutrient deficiencies. This same fortification technology represents an underutilized opportunity for countries where micronutrient malnutrition remains a public health problem.

In recent years food fortification to end micronutrient malnutrition has become a more realistic and accessible option for developing countries. The proliferation of modern food processing and packaging technologies has touched virtually every nation. Populations who regularly consume commercially processed foods are expanding enormously. Newly developed fortificant forms are more stable, bioavailable and cost-effective. Food technologists have created processes which minimize the impact of fortification on the taste and color of food. Models for collaboration among governments, food companies, NGOs and international agencies to fortify foods have been established. Documented impacts from Latin America, Asia and Africa make the case for fortification increasingly compelling.

The progress is heartening. The potential is enormous. But the fact remains that introducing fortificants into the food supply is a broad based effort. Bottlenecks in communication among nutritionists, food technologists, government regulators, and public health officials often result in misunderstandings over feasibility, safety and cost of food fortification. Clear assessments of technology and market conditions are essential for communicating across these professions and sectors. These are a prerequisite to reaching a multisectoral consensus and adapting to the specific national market and public health circumstances.

A key to the achievement of international goals for the elimination of micronutrient deficiencies is the rapid transfer of successful technologies and strategies from one nation to the next. While every nation must define its own strategy to end micronutrient malnutrition, every successful national experience offers a model from which others can learn. Success stories are needed to clarify technical issues, build trust and rally the multisectoral partnership that can make fortified foods more widely available throughout the developing world. *Food Fortification to End Micronutrient Malnutrition: State of the Art* is our effort to tell them.

The Organizing Committee

Food Fortification to End Micronutrient Malnutrition: State of the Art

Micronutrient Initiative
Ottawa, Canada

Eliminating Micronutrient Malnutrition

The second half of this century witnessed enormous strides in eliminating classical famine and malnutrition. The green revolution, new food technologies, emerging markets and improving economies have succeeded in delivering more calories and protein to more people than ever before. While deficits in protein energy linked to adequate food intake continues to cause concern, the key to continued progress in overcoming global malnutrition is a focus on quality in addition to quantity of food.

Over the past decade dietary inadequacies in minute amounts of key vitamins and minerals have emerged as the most widespread and devastating nutritional deficiency on earth. While the clinical impacts of iron, vitamin A and iodine deficiencies have been known for much of this century, only recently have scientists understood that some of the most devastating and widespread consequences result from marginal or “subclinical” levels. Only in the past decade have the crushing consequences of these moderately low or subclinical levels of micronutrient malnutrition on survival, intelligence, growth and development been documented. The prevalence extends far beyond the acutely disadvantaged segments that are vulnerable to clinical manifestations of malnutrition. In fact, the population at risk of Vitamin A Deficiency (VAD), Iron Deficiency Anemia (IDA) and Iodine Deficiency Disorders (IDD) has been estimated at up to three billion people.

Along with a growing understanding of the extent and impact of

micronutrient malnutrition, a number of interventions have demonstrated both the feasibility and the benefits of correction and prevention. Inexpensive and effective solutions are available. Distributing inexpensive capsules, diversifying to include more micronutrient rich foods, or fortifying commonly consumed foods can make an enormous difference. Programs achieving these results have been piloted and positive results evaluated. The conclusions are inescapable. Micronutrient malnutrition is as preventable as it is devastating. Responding to this new understanding of micronutrient malnutrition, at the beginning of this decade heads of state from nearly 160 nations established global goals for the virtual elimination of VAD and IDD and the reduction by one third of IDA.

Impact of Correcting Micronutrient Deficiencies

- Preventing up to four out of ten childhood deaths
- Lowering the maternal deaths by more than one third
- Increasing work capacity up to 40%
- Improving population IQ by 10-15 points
- Raising Gross Domestic Product (GDP) by up to 5%

Proven and Tested Strategy

Since the early 20th century food fortification has reduced and eliminated micronutrient deficiencies in many countries. Salt iodization began in Switzerland during the early part of the century. Margarine fortified with vitamin A was introduced to Denmark in 1918. During the 1930s and 1940s milk was fortified with vitamin A and flour was fortified with iron and B complex vitamins in a number of industrialized countries. In Canada, anemia and Vitamin A Deficiency ceased to be a public health problem in Newfoundland only after the fortification of margarine and flour in 1945. As a result, in addition to the virtual elimination of Vitamin A Deficiency and Iodine Deficiency Disorders and the substantial reduction of Iron Deficiency Anemia, diseases as varied as xerophthalmia, pellagra, beri-beri, rickets, goiter and ariboflavinosis have essentially disappeared from Europe and North America.

In the last seven years, the contribution of salt fortification towards the virtual elimination of IDD in developing countries has been substantial. In most nations where IDD was recognized as a public health problem at the beginning of this decade, an average of 60-70% of all salt is now iodized. Bolivia and Ecuador have been officially certified IDD-free. In African nations like Nigeria, Madagascar and Eritrea more than 80% of current salt production is iodized. As a result, about 12 million infants born in 1996 were spared the consequences of IDD. The number of babies born cretins has been more than cut in half, from about 120,000 in 1990 to less than 55,000 last year. The stage is set for the elimination of Iodine Deficiency Disorders by the end of this decade.

During the 1990s, food fortification has also played a major role in substantially reducing vitamin A and iron deficiencies. A national sugar fortification program in Guatemala has virtually eliminated VAD as a public health problem in that country. Flour fortification in Chile and Venezuela are substantially improving iron status across all sectors of the population. Today in Latin America, Asia and Africa consumers of fortified products as varied as margarine, milk, noodles, chocolate powder and corn starch are substantially protected from a range of micronutrient deficiencies.

Strategic Advantages

Food fortification cannot reach all populations deficient in essential micronutrients. When access to commercially or centrally processed foods is limited, due to geography, poverty or cultural preference, public health and welfare approaches to deliver supplements or dietary education are often the only viable option. However, for the large and expanding populations that regularly purchase and consume commercially processed foods, fortification can make an enormous difference. Within this context of complementary strategies, presentations at *Food Fortification to End Micronutrient Malnutrition: State of the Art* illustrated that fortification may offer a number of strategic advantages.

Engaging New Resources

Continuously protecting nearly three billion people requires an effort beyond the capacity of public health and development organizations. By building on the existing food production and distribution infrastructure, fortification engages the market system and the private food sector. Industry provides much of the initial investment and ultimate financing is borne by consumers. For governments and public agencies, alliances with the private sector offer new sources of capital, technical expertise in production and marketing and, perhaps most important, a business-like approach to solving problems.

Modest Investment

Capital investment in fortification technology is minimal and easily amortized. Ongoing costs of fortificant, marketing and quality assurance are usually absorbed in the normal market price fluctuations for most foods. Incremental costs, usually ranging as low as 0.5-1% are either passed along to the consumer or simply absorbed by food companies. In Thailand, fortification added \$.08 or .05% to the cost of a packet of noodles. However, this may be indiscernible to the consumer who experienced a price increase on the scale of 15-20% due to inflation. Although producers in Guatemala spend over \$2 million annually on fortification of sugar with vitamin A, the price rise in sugar is about equal to rises in the price of corn tortillas and about 28% less than the rise in the price of beans in that country.

Relative Cost Effectiveness

Fortification reaches broad populations at minimal cost. In Guatemala sugar fortification protects the entire population for less than one-quarter of the cost of supplementation. The cost for covering each "at risk" person is \$.98 for fortification as opposed to \$1.52 for supplementation targeting pre-school children only, and \$3.63 for increasing consumption of micronutrient rich foods. In Peru, a school breakfast program which cost \$.22 per portion added a fortified drink component for an additional cost of 1.9%. The prevalence of anemia among the children fell from 66% to 14%.

Builds on Simple and Familiar Technology

For many industries all over the world the addition of conditioners, preservatives, and vitamins and minerals is nothing new. Flour millers in many nations routinely restore iron and other nutrients lost in processing. In other cases, food producers capitalize on fortification as a marketing feature to differentiate their product. For many industries capital investments have been made, dosing and other equipment are already integrated into the process flow, and personnel are familiar with fortification.

Globalization of the Food Industry

As the food industry becomes increasingly global, investment capital and modern technology are accessible to virtually every nation. Accelerating international trade means adequately fortified products can be more easily transferred from one nation to another. Suppliers of fortificants, premix and process technology are expanding their services and marketing on an international basis.

Capitalizes on Demographic Trends

As poor urban populations explode and rural farmers look increasingly to cash crops, fewer people will grow and consume the food farmers grow. Consequently, the market for commercial processed and packaged foods expands dramatically. These changes in dietary habits and consumption patterns offer new opportunities to deliver essential micronutrients through fortified processed and packaged foods.

Help Focus Other Public Health Strategies

With fortification programs in place protecting the bulk of the population who participate regularly in commercial food markets, efforts to deliver supplements and dietary education can focus resources on remote and disadvantaged populations that have limited access to fortified foods.

Sustainability

Eliminated in one generation, micronutrient deficiencies will crop up in the next if essential nutrients are not continuously provided. Unlike classic disease eradication campaigns such as smallpox or polio, once elimination of micronutrient malnutrition is achieved, the threat continues if the intake of micronutrients becomes inadequate again. Consequently, the key for micronutrient strategies is sustainability of adequate intake over the lifetime. Fortification is a market-based strategy which builds on private investment and consumer demand. Among producers it becomes a way of doing business and becomes permanently integrated with the food processing and distribution system. Among consumers it becomes a habitual purchasing preference. These market forces will sustain fortification long after the initial "elimination" of micronutrient malnutrition has been achieved.

Strategic Approaches to Food Vehicles

While clinical levels of VAD have been halved during this decade, progress towards the virtual elimination of VAD and reduction of IDA by one-third of 1990 levels has not been as dramatic as salt iodization to eliminate IDD. However, for a number of technical reasons, a single food vehicle to achieve the elimination of both VAD and IDA is not yet available. Although new technologies are in development, the double fortification of salt with iron and iodine is not yet ready for wide-spread application.

Presentations at *Food Fortification to End Micronutrient Malnutrition: State of the Art* demonstrated a spectrum of strategic approaches to a variety of potential vehicles for fortification. In some nations a single vehicle may provide substantial protection. For example, sugar is proving to be an important source of vitamin A for most populations in Guatemala. Iron fortified wheat flour is improving iron status in Chile. In these cases, a single serving of the fortified food is designed to offer a substantial proportion of daily requirements for a particular micronutrient. However, many nations encompass a variety of culinary habits and may feature inconsistent dietary intakes across different populations. In these cases, no single vehicle for fortification may be sufficient.

For many nations, a variety of vehicles, each fortified with a more modest proportion of RDI, may offer an effective option. If consumption of a particular food is consistent in some groups but only sporadic in others, fortifying several vehicles provides for complementary coverage. In other words, coverage provided by one food vehicle can "fill in the gaps" in the distribution of consumption of another. In the case of Venezuela, a combination of fortified corn flour and wheat flour was selected in order to achieve population-wide coverage. In the Philippines, a variety of vehicles including margarine, flour, noodles and sugar will offer protection from micronutrient deficiency for specific consumer segments. When considering a multi-faceted approach, each food vehicle offers specific opportunities and constraints.

Cereals

Inexpensive staples like rice, corn and wheat flour reach the broadest populations. In some countries, staples are increasingly being milled centrally and can be fortified effectively. In others, these foods are often eaten where they are grown and processed in small community facilities. This effectively limits fortification opportunities to ensure quality and safety.

Fats and Oils

While intake of fats and oils is generally not high enough to supply 100% RDA through fortification, it may successfully supply a portion. For example, in some urban populations in India, fortified *vanaspathi* (hydrogenated fat) contributes to 21% of RDA for vitamin A.

Dairy Products

In many cases, milk consumption is particularly high among groups most at risk for micronutrient deficiencies i.e. mothers and children. In several urban centres milk is processed in large dairies, however, cost, distribution and other factors may limit accessibility among vulnerable populations in rural areas.

Condiments

Sugar, spices, starches and sauces are efficient carriers and often are consumed in regular quantities throughout the population. In Southeast Asia they offer great potential. However, due to cost, custom and other factors, consumption may be inconsistent across socio-economic groups or even among family members.

Value-Added Products

Consumer awareness, technical breakthroughs and marketing innovations often emerge from the development of value-added products. However, these higher priced products may be consumed only sporadically by the most vulnerable populations.

The fortification of a number of foods offers several key strategic advantages. When a variety of food sectors are engaged, no single industry sector can resist on the grounds that it is being unfairly singled out. When a variety of food products is fortified, each with a lesser proportion of RDI, the theoretical possibility of consuming dangerous levels of a micronutrient through the consumption of large amounts of a single food becomes more remote.

Unlike many global health goals there is no international template for action. Fortification options need to be considered on a nation-by-nation, market-by-market and food-by-food basis. While this process has been painstaking and halting, it has begun. The cases presented at the *Food Fortification to End Micronutrient Malnutrition: State of the Art* indicated that this strategic approach to food vehicles is showing results and is beginning to affirm the promise of food fortification technologies to end micronutrient malnutrition.

Fortification Technologies: State of the Art

The efficacy of food fortification in reducing the prevalence of nutritional deficiencies has been proven mainly in countries with relatively sophisticated food processing, distribution and marketing systems. In many developing countries where micronutrient malnutrition remains a public health problem, a variety of products are voluntarily fortified. However, most of these are beyond the purchasing power of the majority of the consumers. The meeting on state-of-the-art for food fortification to end micronutrient malnutrition focuses not only on whether the technology works, but rather on how it can be cost-effectively adapted in situations where production and distribution systems are relatively unsophisticated and where consumers have relatively low purchasing power.

The objective is to identify rugged technology that can keep costs down while delivering efficacious levels of vitamins and minerals to the consumer. For example, in the more developed markets where the salt is extremely pure and packaging is airtight and water-proof, potassium iodide is used in fortifying salt. However, iodide is not suited for the warmth and dampness that seeps through the more rudimentary packaging used in developing countries. As a result, potassium iodate has been developed for addition to salt to eliminate IDD where quality of salt is not optimal. A number of recent advances minimize required investment and reduce fortificant losses while they increase cost-effectiveness.

More Robust Fortificant Forms

New micro-encapsulation technologies render fortificants more resistant to destructive elements in the environment. Micro-encapsulation of vitamin A in powder form has substantially reduced fortificant losses in products as varied as sugar, wheat flour, instant powdered beverages and pastas. Encapsulation of iodine and iron in salt can separate them by a barrier and keep them stable. When losses from light, heat and moisture during production, distribution or cooking are kept to a minimum, less fortificant is needed to reach the consumer with sufficient levels of essential micronutrients.

Increased Bioavailability

Often deficiencies persist even when diets contain sufficient micronutrient-rich foods because the nutrients are not efficiently absorbed by the body. Iron EDTA and other advanced compounds can increase absorption by up to 250% over traditional forms by releasing the iron available in the food for human absorption. The presence of vitamin C increases the body's ability to absorb iron by a factor of two or three. Although often more expensive by weight, these advanced compounds and mixtures can be used more sparingly and in many cases can be more cost-effectively deliver essential micronutrients to the consumer.

More Stable Fortificant Forms and Mixtures

New fortificant forms and mixtures resist interaction with other compounds in the food vehicles, minimizing organoleptic changes, increasing effective shelf-life and maximizing consumer acceptance. Iron fortification of milk is now possible with a new technology which limits interactions altering appearance and taste. By mixing two iron forms, rather than simply relying on one compound, Venezuelan millers cut down on the interactions which had previously turned the local baked product an unappetizing green.

New Bonding Systems

Improved bonding technologies to more efficiently adhere fortificant compounds to the food vehicle result in less segregation of food and fortificant and therefore reduce waste. This is particularly important in the fortification of condiments or powders where the fortificant can disengage or separate from the vehicle during the production process or storage. Recently, research using different oils as a binding agent for bonding vitamin A to sugar has resulted in more than doubling the retention rate of vitamin A during the dosing process.

Development of Standard Premixes

Adding a fortificant under the unsophisticated conditions found at food processing facilities in many developing countries, is often quite difficult. Newly developed pre-mixes of vitamins and minerals tailored to a country's needs simplify the process and lower technical barriers in application. There is no need to individually weigh and feed tiny amounts of micronutrients. Purchasing and inventory are streamlined because processors can buy and stock just one item, the premix. Finally, since the premix delivers standard and constant proportions of the various micronutrients, in-plant quality control technicians need only trace one of the fortificants to assure that all are being added in proper amounts.

Refined Process Technology

As fortification technology is integrated into the overall production process, it becomes more efficient and cost-effective. Investments in sugar fortification have led to improved vitamin A dosing systems. New mixing and feeding systems in salt plants are also leading to a number of efficiencies. For example, with a recent World Bank loan, China is upgrading its salt processing facilities and expects an improvement in salt iodine retention of up to 80%.

These kinds of technical advances are making fortification a more viable and cost-effective option in developing countries. Cases presented at the *Food Fortification to End Micronutrient Malnutrition: State of the Art* meeting also illustrated how individual nations are introducing and adapting these technologies to address their specific deficiencies as well as the state of their food industry and markets. Each successful adaptation lowers barriers, reduces risks and decreases costs for ensuing efforts. The state of the art is always dynamic.

Public-Private Collaboration: State of the Art

Food companies have developed numerous compounds which are added to food products in order to maintain product consistency, improve or maintain nutritional value, maintain palatability and wholesomeness, provide leavening or control acidity/alkalinity or enhance flavor or impart desired color. Even in cases where food additives are introduced by industry for purely commercial reasons, the public-private discourse over issues of regulation, labeling, advertising, safety and consumer protection is quite complex. When the goal is to fortify foods as a public health intervention this dialogue becomes more intricate. Food fortification for the purpose of ending micronutrient malnutrition involves opening new communication channels among the public health community, research institutions, government regulators, food companies, and a variety of civic and consumer organizations.

Foods fortified to end micronutrient malnutrition must be designed both as effective micronutrient delivery vehicles as well as attractive commercial food products. The cases presented at the meeting define a series of multisectoral communications critical to implementing fortification as both a public intervention and as a private sector investment.

Transferring Public Health Research to a Wider Audience

Initial steps to communicate the extent, impacts and solutions of micronutrient malnutrition to a broader multisectoral audience emerge from a range of non-governmental organizations, often with the support of international agencies and donors. These groups play a pivotal role in opening communications between government and private industry and garnering a general commitment on the part of the public and decision makers to explore the feasibility of food fortification.

Collaborative Technical Assessments

Determining the potential for food fortification to end micronutrient malnutrition requires a blend of information, skills and resources found in a variety of distinct public and private organizations. For example, initial assessments may involve overlaying private sector data on market consumption with public research on the distribution of the micronutrient deficiencies. Public sector institutions bring expertise in analyzing potential biological impact. Private sector food technologists assess organoleptic changes in food products. Cases presented at the conference described a number of organizational options to accomplish these hybrid public-private tasks, ranging from informal task forces operating under the umbrella of research institutions to presidential appointments of official government commissions.

Balancing Interests

Beyond the multisectoral technical exchange of information to identify options, successful food fortification to end micronutrient malnutrition entails opening a policy dialogue to resolve the varying interests and perspectives of public and private organizations. Public sector interest in efficacy among the most vulnerable populations must be balanced with private concerns about cost, commercial viability and consumer acceptance. In Venezuela, a multisectoral commission negotiated an amended fortification profile for corn flour in order to ensure bioavailability to meet the criteria set up in the public health community with apprehensions about consumer acceptance voiced by industry.

Sharing Costs

While the initial investment in fortification is quite modest, unless these costs are borne fairly, they will present barriers. Negotiation among the stakeholders works to determine how those costs and risks are to be shared. Cases presented at the conference included distribution of fortified products through schools and public health agencies; simplified product registration procedures; and tariff reductions on fortificant and value added tax (VAT) reductions.

Combining Public Commitment with Private Enterprise

Successful food fortification programs often involve blending the strengths of public and private communications. The public sector brings a reputation for scientific integrity, concern for consumer safety, and special access to the media and high profile public personalities and symbols. The private sector brings skills in message development and a focus on maximum persuasion and impact. Speakers from a number of nations described joint communications to overcome objections and skepticism among professional and scientific groups as well as joint public education to raise consumer awareness.

The hallmark of successful fortification programs presented at the meeting is the creation of new hybrid communication channels which can assist in the design and assessment of food fortification as both public health interventions and private food company investments. Some cases involve national legislation mandating fortification of a common food consumed by the general population. Others involve food companies making market-based decisions to fortify specific products or product lines targeting specific market segments. All involve a sharing of information, a balancing of interests and ultimately a joint investment of public agencies, private business and non-governmental organizations.

Micronutrient Fortification of Foods

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Introduction

Micronutrient fortification technology makes possible nutrient delivery systems that apply to a range of food systems. These can be quite diverse, and we can use technology to apply them across cultures. In both developed and developing countries micronutrient food fortification has either thwarted micronutrient malnutrition or demonstrated the capacity to resolve it.

Adding micronutrients to food, in contrast to providing vitamin supplements, significantly decreases many safety concerns. After all, there is a limit to how much fortified food people can eat at one time. On the other hand, supplements can be discovered by children and have been known to cause overdose problems. There is rare isolated evidence of overdose problems caused by eating foods that have been mis-fortified. Adding micronutrients enhances the nutrient balance and bioavailability of the diet safely and at low cost.

A full RDA of vitamins can be incorporated into food for less than one cent per day. Fortification technology is widespread, available and rarely the limiting factor.

Micronutrients are added in microgram and milligram quantities, and are theoretically invisible because the addition is diluted into the matrix of the macromolecule that gives food its structure. This invisibility means the absence of any kind of color or flavor or other effects from the added nutrients. Ironically, this attribute may also account for the occurrence of malnutrition, because the presence of nutrients or the lack of nutrients in a food cannot be physiologically perceived. For example, there is no way of people knowing whether their flour is enriched or not enriched.

A Comprehensive Approach

Malnutrition is catalogued by individual nutrient deficiencies. If night blindness occurs due to lack of vitamin A, we look at that individual nutrient. Yet the pathogenesis, or the development of disease, tells us that there are several nutrients involved in the functional solution of the malnutrition problem. Once we remove the first limiting nutrient for a specific deficiency, we must then consider the next nutrient, which has in turn become the limiting one. Consider a case where lysine is a limiting nutrient and lysine is then added to the food. In corn the next limiting nutrient will become tryptophan. In rice the limiting nutrient will become threonine. Another nutrient will emerge as the limiting one because the food is not a perfect one. Another example can be found in the case of elevated homocysteine. This chronic condition is not going to be

found in the case of elevated homocysteine. This chronic condition is not going to be solved by paying attention to just one nutrient, like folic acid. One must consider that folic acid functions with B₁₂ and that to lower homocysteine you also need B₆ and magnesium. If one really wants to solve the problem one must consider the total biochemistry of the phenomenon.

In developed countries, in order to thwart chronic degenerative diseases such as osteoporosis, mother nature should be our guide. If we restore only one or a few nutrients when we know that several are limiting, we are remiss in not practicing full restoration. We cannot fully solve the problem by just adding calcium when we also need vitamin C, protein, zinc, copper and manganese.

The pathology of a single micronutrient deficiency may be benefited by fortification. There is no question that you can have an impact on goiter with iodine. However, this may simply postpone the benefits of the more optimal bioavailability of nutrients on the sum of all the biochemical and physiological processes concerned with the growth, maintenance and resistance to stress on the body – the true definition of nutrition.

This dichotomy exists because the practice of medicine evolved from the study of pathology, which means that people are taught to look at deficiencies by seeing the pathology first then trying to find a reason for it. Whereas the practice of nutrition and public health evolved from the study of thwarting pathogenesis by preventing the beginning of disease in the first place, thus optimizing health and concomitant performance.

A Responsible Approach to Fortification

Unless micronutrients can be delivered in quantities needed, it is difficult to expect a single food ingredient or a condiment, in contrast to a whole intact food, to serve as an ideal vehicle. Iodine added to salt is a suitable practice, but the addition of vitamin A to monosodium glutamate may not be a suitable practice. Either the carrier vehicle must make a substantial contribution to the diet or it must be a very common ingredient of formulated foods. Somehow, this principle was overlooked for quite awhile. People kept trying to add nutrients indiscriminately, trying to push the technology too far and raising unrealistic expectations and results. It is smarter to add micronutrients to more common foods that everybody eats.

Fabricated foods are foods that emulate or mimic a known food but are composed of a different array of ingredients. These must either contain or be fortified with the micronutrients of the product being emulated. Although in fabricating food, you only are manipulating macronutrients, you must also pay attention to the micronutrients. For example, margarine emulates butter. However, a responsible approach takes into account that this fabricated food must be a source of vitamin A, some carotenes and vitamin D. Fruit roll-ups are a good example of overlooked fortification. Fruit roll-ups are made of material from the fruit itself and a few extra added ingredients like pectin that are natural to the product. However, there is no vitamin C or other vitamins and no folic acid. Parents buy this food to feed to their children thinking that if the products are made from fruit they must have fruit nutrients. They do not, however, because no one has been responsible enough to restore them.

The possibility of micronutrient excess exists, but even in developed countries the incidence has been exceedingly rare. In the United States there was one case in the Boston area where a tremendous amount of vitamin D was added to milk in one dairy and people were getting vitamin D toxicity symptoms. The addition of these high doses of Vitamin D must have cost a fortune, and just from a cost point of view someone should have been looking at where all the money was going! Clearly, the quality control system at that plant left a lot to be desired. However, these errors during fortification are exceedingly rare. The public health experience over the last 50 years attests to the overall benefits and safety of food fortification.

Criteria for Effective Food Fortification

There is considerable art involved in the incorporation of an array of micronutrients into a food product. Even the steps and the sequence of additions can affect the finished food product. We do not understand all of the underlying chemistry, thus fortification technology requires experience. We must realize that in many areas the food technology has preceded the science by many years. The examples are myriad. Louis Pasteur explained the benefits of food preservation by heating many years after it was first practiced (1803).

Minerals pose unique problems. Even at very stable deterioration rates they are not inert and can be a cause of reactive deterioration, such as oxidization. For example, you do not want to mix iron with vitamin C or E. This means that the blending of minerals and vitamins must occur at low temperatures and with minimal moisture. Vitamins can be coated using a protein so that they can be mixed in with other vitamins and minerals. Otherwise, color changes, flavor changes, texture changes, or all three, will result.

Micronutrients should be stable and bioavailable. They should not cause color, flavor or texture changes. After baking, going through an aeration machine, or sitting in a consumer kitchen they should still be there with not too much loss. Bioavailability should be measured objectively by testing physiological levels in blood or urine.

Public health criteria also should play a part in micronutrient fortification. There are three criteria generally expected by public health specialists in evaluating the need and efficacy of a public health policy. First, will the policy benefit a significant proportion of the population? Certainly that was true in the United States in 1943 when there were several hundred thousand cases of pellagra and almost as many cases of ariboflavinosis and beri-beri affecting people at all different income levels. Second, will the policy reach those that are the most needy or the most vulnerable? Is this a food or a vehicle that is eaten by everybody, especially the poor? It is a good idea to fortify a basic staple, whether it be tortillas or *arepas* or bread or something most people are going to eat most of the time.

The third consideration is the cost of the policy. Is it economically balanced in relation to other potential expenditures? If there is no action taken, will there be an increase in medical care costs? There are data available now that show that we can save money in medical care costs by proper use of fortified foods. If the answer to these and other question is yes, then a practical public health policy is possible and should be considered very seriously.

The Impact of Fortification

Examples of the achievements of fortification in the United States and in other countries are the elimination of beri-beri, ariboflavinosis, pellegra, rickets and goiter. A number of studies demonstrate the thwarting of vitamin A deficiency and in particular blindness. There was a major reduction in health care costs in the at-risk population of women and children in utero to age five by the combination of nutrient-dense foods and fortified foods. This was accomplished through the Women, Infants, and Children program (WIC), which has been the most significant and most powerful nutrition intervention of all our programs in the United States. The United States has spent billions of dollars on food stamps, and although we have made a dent in basic hunger, we have shown no impact on nutrition status.

With WIC we have actually seen benefits with reduced cost of health care in children. The supplemental food program for WIC provides fortified foods and cheese and eggs and various energy-dense foods. In a study done in five states, for each dollar spent on WIC between \$1.77 and \$3.13 was saved in Medicaid cost for newborn infants and between \$2.84 and \$3.90 was saved for newborns in the first 60 days post-partum. For every dollar invested there was as much as a \$4 return. That is a very good public health investment.

Before World War II President Franklin Delano Roosevelt executed Food Order #1, which stated that all corn, wheat and rice products must be enriched with thiamin, riboflavin, niacin and iron and optional calcium. That began to have an immediate impact. Enrichment legally became promulgated and mandatory in a number of states. By 1948, three years after the war, 22 states required enrichment. Since anybody selling food across state lines had to comply, everyone adopted the enrichment standards. Then mandatory federal enrichment legislation took over. The number of deaths from pellegra dropped from 3,200 essentially down to zero by 1954. Today, in the U.S., if you removed fortification, it is highly likely that you would have cases of beri-beri, pellegra and ariboflavinosis, because about 25% of the total intake of these nutrients in the U.S. diet is provided from fortification.

Fortification of Corn Flour in Guatemala: 1972 - 1976

Years ago I was involved in one of the more powerful nutrition experiments ever conducted in Guatemala, in Santa Maria Canqul on the Pan American Highway north of Guatemala City. There was a need to improve the protein in the diet, so we decided to use soy flour to effectively make a 5% addition. We also added lysine, thiamin, riboflavin, niacin, a highly stable and non-interfering kind of iron and a coated vitamin A called 250 SD. We also added corn starch as a filler. From 1972 to 1976 the consumer in this area had the opportunity to select, or not select, the addition. It was added in 5% of their own corn *masa*, ground corn ready to make into tortillas.

The fortification was made available at the village millers in a unique way. There was a scale that went from number 1 to 20 along with a series of ladles in corresponding sizes. As the corn to be milled was weighed, the scale would point to a specific number which would in turn correspond to a specific ladle. The mill manager would pick up a corresponding ladle and add the fortification mix into the corn before it was put through the mill. The mixture was then ground and available to take home. The cost was a penny or two paid to the miller. We kept track of each house by giving them a plastic dish in which to carry their corn. We registered which houses selected the addition and we monitored all the pregnant women in the village and their children.

We compared the group who did not take the mixture very often to the group that took it on more than 60% of the daily occasions. Out of a total of 304 births, 189 mothers had not taken the addition and 115 had selected the fortified option at the millers. The death rate for all births was 25 out of 189, or 132 per thousand. Data from a study several years before this showed that out of 504 deliveries the death rate was 121 per thousand with a range of 107 to 133. For those who took the fortification mix the death rate dropped to 5 out of 115 or 44 per thousand. For babies at full term who weighed 2500 grams, the mortality rate dropped from 112 per thousand to 42. But even for babies less than 2500 grams the death rate dropped from 192 per thousand to 47.

You can see that the nutrients added to corn flour had a tremendous impact on infant mortality. We also evaluated impact on the mortality rate of the brothers and sisters who were 2 to 5 years of age. Even at this stage you could see a change in the death rate. Before fortification, the death rate was 57 per thousand for two year olds, 33 per thousand for three year olds, 13 per thousand for 4 year olds, and 3 per thousand for five years old. The death rate for those who did not take the supplement was 48, 18, 41, and 10, for an average of 31, which is about the same as the previous average of 29. In the group of brothers and sisters who used the fortified corn flour, the drop in the mortality rate was 50% to 24, then 8, then 0 with an average of just 10. This is one-third of what it had been in the past. Our data on the incidence and number of days of diarrhea and upper respiratory tract infections also showed dramatic changes and are not reported here.

The Future of Fortification

The future of suitably applied fortification technology is the elimination of micronutrient malnutrition with a concomitant increase in the effectiveness of limited quantities of available protein. Increasing the effectiveness of the protein supply would be beneficial since protein is the most costly nutrient. In developed countries excess protein, the most expensive of essential nutrients, is wasted as a source of energy. In developing countries protein, the biochemical kingpin of metabolism, is often unbalanced in quality and sometimes constrained in quantity. Fortification, coupled with micronutrients, can exert substantial public health results even in the presence of insufficient energy intake.

Oils, Fats and Margarine



Oils, Fats and Margarine: Overview of Technology

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Abstract Vegetable oils are consumed by almost everyone. Production and consumption are increasing worldwide. The technology of fortifying fats with vitamin A, an oil soluble vitamin, is relatively easy and inexpensive. In most countries oil production is fairly centralized. Therefore, from a technical point of view this is a very viable food vehicle to deliver micronutrients. Limiting factors include: the quality of the oil itself, packaging materials that protect vitamin A from ultraviolet light and culinary habits such as repeated use of the oils in frying. In addition to vitamins A, D and E, technologies now exist to add water-soluble micronutrients including vitamins C, B complex, iron and calcium.

Introduction

Fats and oils represent an important class of food components. They are important because they supply a concentrated source of energy, essential fatty acids, and oil soluble vitamins such as vitamin A, vitamin D and vitamin E. Fats and oils are used in most areas of the world in food preparation. Thus, fats and oils must be considered an important food constituent when evolving strategies to overcome micronutrient deficiencies.

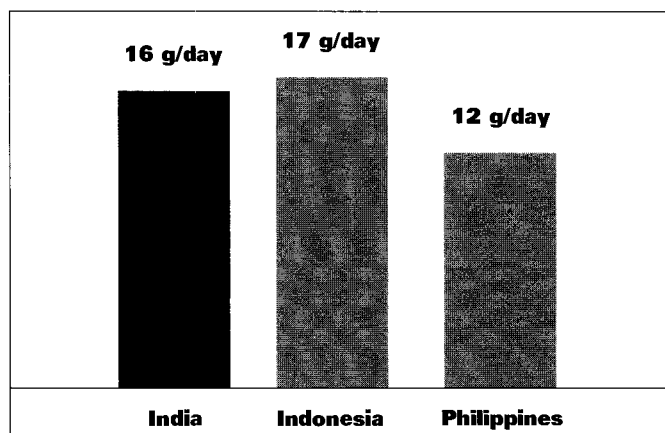
Rationale

Many areas of the world suffer from a lack of the oily vitamins, notably vitamin A. Infants and children are especially at risk. Fats and oils are vehicles which could be used successfully to combat deficiencies of these nutrients. Fats and oils are important ingredients in the diet throughout the world. They provide a concentrated source of energy and supply many vital nutrients. Because they are a staple food item, they could be very useful for supplying needed micronutrients to target populations.

The world-wide production of vegetable oils is high and their consumption is increasing. This is true even among the lower socioeconomic groups. For example,

the FAO reported that India had a production of almost 20 million metric tons of oil with a per capita consumption of 16 grams per day. Indonesia had a production of about 14 million metric tons with a consumption of 17 grams per day and the Philippines had a production of about 9 million metric tons and a consumption of 12 grams per day. The consumption of vegetable oils is nutritionally preferred over animal sources. Vegetable oils contain less saturated fat and have no cholesterol.

Per Capita Consumption of Vegetables Oils



Soybean oil and palm oil account for about 50% of the vegetable and marine oils consumed annually world wide. These are followed by rapeseed or canola oil and sunflower oil. In the US, almost 60% of the edible fats and oils consumed are soybean oil. The next closest in consumption are canola oil and corn oil at 6% each.

Vegetable oils are consumed by almost everyone. Therefore, they could be used as a vehicle to improve the diet with fat-soluble vitamins by fortification. The technology for fortification of fats and oils with vitamins A, D, and E is relatively easy and, because in most countries oil production is fairly centralized, the logistics of fortification are simpler than with many other types of food products.

Basic Properties of the Fat-Soluble Vitamins

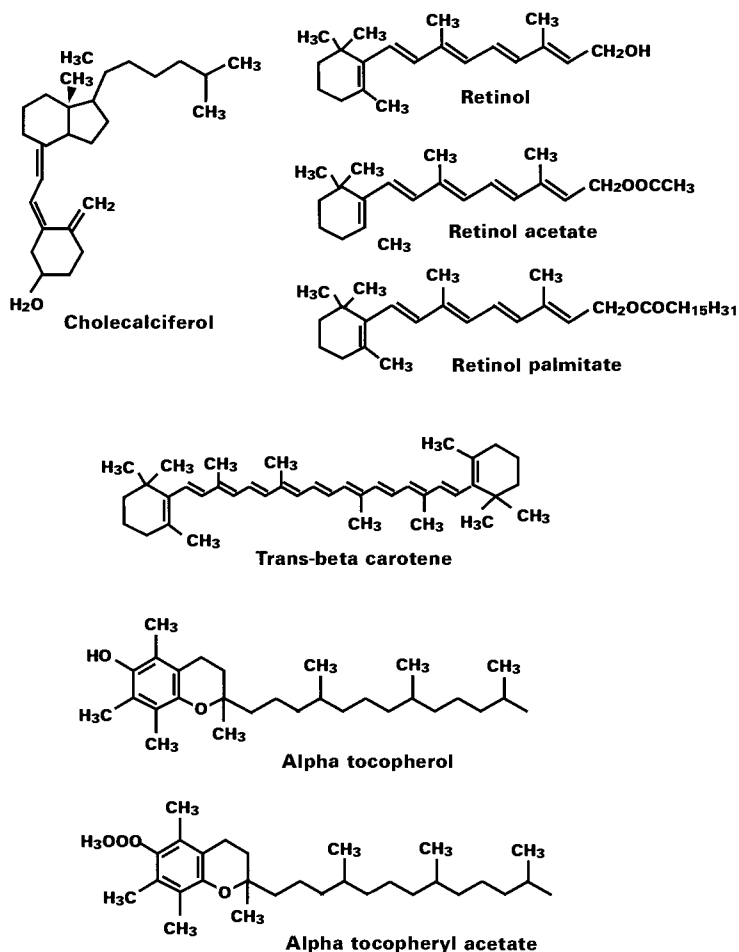
The three vitamins that could be used for fortifying fats, oils and margarines are vitamin A, vitamin D and vitamin E. The commercially available forms of vitamin A are retinyl palmitate and retinyl acetate. For vitamin D, cholecalciferol is widely available. For vitamin E, dl- α -tocopheryl acetate is most commonly used. In general, retinol and dl- α -tocopherol are not used as vitamins in food fortification because of their instability. Beta carotene can also be used to supply vitamin A activity, but it also adds color which may or may not be desirable.

From a physical/chemical perspective, these vitamins have some common features. They all are oxygenated alicyclic or aromatic hydrocarbons. They all have some degree of unsaturation, which makes them susceptible to oxidation. All these vitamin forms have moderate molecular weights, in the range of 400 to 500. They are all soluble in organic solvents, including fats and oils and are insoluble in water. Beta carotene is provitamin A and is a hydrocarbon. It has vitamin A activity but is less toxic than preformed vitamin A, as the body has a feedback mechanism for the conversion to vitamin A.

Fats and Oils Production

Fats and oils come from two sources: animals and oilseeds. Marine sources are also available, but their use is very limited. This section will focus on the animal and oilseed sources. One of two processes can be used to refine the fats and oils: chemical and/or physical. Animal fats can be obtained by the process of rendering. Rendering requires that heat be applied to fat-containing tissues to separate the fat from the tissue protein. Examples of this type of fat include lard and tallow.

Fat Soluble Vitamins



Vegetable fats and oils are usually obtained from oilseeds by crushing and filtration. Heat and solvents such as hexane can be used to improve yield. These first-pressed oils are crude oils and generally require further refining to remove undesirable components such as proteins, phospholipids, free fatty acids, etc. These materials can cause allergic reactions, oxidative instability, and odor and flavor problems. Often these further refinements can also remove some desirable components such as tocopherols and carotenoids.

Chemical refining requires that the crude oil be treated with caustic. This treatment causes free fatty acids to be transformed into soaps that are water soluble and can be removed by centrifugation. The process also removes other undesirable materials such as proteins. Any remaining water is removed by drying. The next step is to bleach the oil to remove colorants. This process removes carotenes and chlorophyll. Bleaching is

normally accomplished with an adsorbent, such as a clay or carbon. Depending on the process, the oil may then be partially hydrogenated to improve its oxidative stability. Hydrogenation is accomplished by treating the oil with gaseous hydrogen in the presence of a catalyst such as nickel. After hydrogenation, the oil is then deodorized to remove any remaining low molecular weight compounds that can catalyze oxidation or cause off odors and off flavors. This process requires the use of vacuum, steam and high temperatures.

Once the oil has been refined, it can then be used as salad oil or for cooking, or it can be further processed into margarine, spreads, dressings or as an ingredient in other products. The nutrients that can be added would most typically be oil-soluble vitamins that could be included alone or in combination as a liquid blend. The vitamins should be added after the final deodorization step to minimize losses due to heating. Antioxidants such as alpha-tocopherol, ascorbyl palmitate, BHA, BHT, TBHQ, etc. can be added also, depending on governmental regulations, to minimize degradation during storage and/or handling. The oily vitamins can be easily mixed into the oil. Because of the high oil miscibility, the only required process is stirring. If beta carotene is added, the most economical form is a suspension of beta carotene crystals in oil that should be added to warm oil. The crystals must be mixed with heating to dissolve and allow uniform distribution. If the oil is to be processed into margarine, this can be done once the oily vitamins have been added.

Margarine is a water-in-oil emulsion, meaning fat is the continuous phase. In the United States, margarine must contain at least 80% fat by weight. The oils used are usually mixed triglycerides of vegetable origin (although animal or marine sources are sometimes used). The predominant oils used in the US are soybean oil and corn oil. These oils are partially hydrogenated to give the desired ratio of solid fat to liquid fat in the final margarine.

Technology of Fortification

Fortification of fats and oils and margarines is technologically feasible. Compared to other food staples, they are also relatively easy to fortify. The oil-soluble vitamins (A, D and E) are readily miscible with food oils. The nutrients can be added to oils individually or as blends. The most commonly used blend contains 1,000,000 IU vitamin A and 100,000 IU vitamin D₃ per gram. The

blend is stabilized with dl-a-tocopherol. For margarines, blends containing vitamin A and beta carotene, with or without vitamin D, are generally used. Commercially available custom blends are also marketed to meet specific requirements. These custom blends can contain any combination of the oily vitamins, as needed.

The actual process of fortification of fats and oils is relatively simple. The appropriate amount of vitamins, with adequate overage, is added to a good quality oil at a temperature of approximately 40 - 45°C. This temperature ensures that the oil is liquid and fluid to make distribution of the vitamins easy and uniform. Mixing is performed and additional antioxidants can be added to extend the shelf life of the fortified oil. Better results can be expected by mixing the antioxidant directly into the vitamins and by adding this premix to the oil. It is impor-

Mandatory Fortification of Margarine

Country	Vitamin A (IU/kg)	Vitamin D (IU/kg)
Belgium	22,500-27,000	2,500-3,000
Brazil	15,000-50,000	500-2,000
Canada	≥ 33,000	5,300
Chile	30,000	3,000
Columbia	3,180-7,950	480-1,200
Denmark	25,200	
Ecuador	20,000-30,000	2,000
El Salvador	15,000	
Guatemala	15,000-50,000	
Honduras	35,000	1,500
India	30,000	
Indonesia	25,000-35,000	2,500-3,500
Malaysia	25,000-35,000	2,500-3,500
Mexico	20,000	2,000
Netherlands	20,000	3,000
Panama	20,000	1,500
Peru	30,000	3,000
Portugal	18,000	
Singapore	28,300	2,200
Sweden	30,000	3,000
Taiwan	45,000	
Turkey	20,000	1,000
USA	33,000	2,080
UK	24,000-30,000	2,800-3,520

tant that a good quality oil is used for fortification. If the oil is partially or fully oxidized to begin with, the stability of the vitamins will be compromised. Once the oil is fortified, it is packaged and cooled. It is important that air tight, and preferably opaque, packaging be used so that the oil will be protected from air and light. A head-space of inert gas will also extend shelf life.

Margarine is prepared by combining an oil phase and an aqueous phase through emulsification. The oil is liquefied by heating and mixed with other oil-soluble ingredients. These ingredients may include surfactants, flavors, colors and vitamins.

In the US, margarine must be fortified to 15,000 IU vitamin A/pound (33,000 IU/kg). The vitamin A may be added as preformed or as beta carotene or both. In general, a combination of vitamin A palmitate and beta carotene (2:1) is used to give a typical color. Vitamin D is an optional ingredient, which if added must be present at 1,500 IU/pound (3,300 IU/kg).

World wide, the ranges for mandatory fortification can vary widely. For example, in Colombia the minimum level of vitamin A is approximately 3,200 IU/kg; in Taiwan the minimum is 45,000 IU/kg. For vitamin D, the minimum ranges from 430 IU/kg in Colombia to 5,300 IU/kg in Canada. For a 15 gm serving, these ranges would equate to between 4% and 51% of the USRDI for vitamin A and between 2% and 20% of the USRDI for vitamin D for preschool children.

In an FAO list of margarine fortification legislation in 37 countries, seven of the countries listed have mandatory fortification legislation whereas 19 countries have voluntary fortification. Of those countries listed, 19 have no specific legislation in place for levels of fortification. Yet 17 of the listed countries have known deficiencies of vitamin A and four have known deficiencies of vitamin D.

Stability of Nutrients in Fats and Oils

The stability of the oily vitamins in fats and oils can be very good, which is one of the benefits of using food oils as vehicles for fortification. Vitamin E ester tends to be very stable under most conditions. The others are susceptible to degradation due to oxygen, heat and light. Metals also can catalyse the destruction of these vitamins.

Care must be taken during processing and storage to ensure that the nutrients will be present at adequate levels when they reach the target populations. One of the primary issues is the quality of the oil that will be forti-

fied. If the oil is of good quality, it will have minimum exposure to oxidation. Once an oil has begun to oxidize, it is extremely difficult to improve its quality. Oils of good quality tend to be good vehicles for vitamins for several reasons. One reason is that oils act as physical barriers to oxygen. By keeping oxygen away from the vitamins, the onset of their degradation is greatly delayed. Another reason is that vegetable fats and oils tend to have natural tocopherols present, which act as antioxidants to protect the oil. The added nutrients are also protected by the same antioxidants. However, the level of

Stability of Vitamin A in Soybean Oil During Cooking

Food	Type of Cooking	Before Cooking	After Cooking	Recovery
White Rice	Boiled	330 µg/g	330 µg/g	100%
Kidney Beans	Boiled	180 µg/g	150 µg/g	83%
Kidney Beans	Pressure	120 µg/g	120 µg/g	100%

these natural antioxidants depends on many factors, and therefore can be highly variable. Therefore, it would be prudent to add antioxidants to fats and oils before adding vitamins to ensure protection of the nutrients.

Vitamin A stability can be very good in fortified oils. Favaro et. al. examined the stability of retinyl palmitate in soybean oil. Oil was fortified at a level of 200 IU/g and packaged in cans. The cans were stored at 23°C: as sealed cans in the dark, as open cans in the dark, and as open cans in the light. The oil stored in sealed cans in the dark retained about 85% of the vitamin A after one year. When opened and in the dark, the oil retained about 66% after one year. Fortified oil stored in open cans in light retained about 50% of the vitamin A after nine months of storage.

Vitamin A can also be quite stable in margarine. Bauernfeind reported the retention of vitamin A in several commercial brands of margarine stored for six months at 5°C and at 23°C. Losses of 2 to 10% were observed when margarines were stored at 5°C. At 23°C losses in the range of up to 15% occurred.

In normal cooking practices vitamin A can be stable. Favaro et. al. evaluated the stability of vitamin A-fortified soybean oil used to cook rice or kidney beans by boiling or pressure cooking. They found little loss of vitamin A. Frying, however, can destroy vitamin A quickly. The amount lost depends upon the number of frying cycles used with the oil.

Vitamin D stability tends to mirror that of vitamin A. The same conditions which add to stability of vitamin A or to its loss will affect vitamin D. In general, vitamin D is stable in fats and oils when protected from oxidation, heat and light.

Vitamin E in the ester form tends to be extremely stable. However, the free tocopherol is unstable to oxidation. Even though many vegetable oils contain natural tocopherols, the levels can be quite variable, depending upon the source, processing conditions and storage conditions. Also, most vegetable oils tend to contain K-tocopherol as the predominant form of the vitamin. This form, while generally a better chemical antioxidant, has much lower vitamin E activity than I-tocopherol. Therefore, fortification can be used to provide improved stability and content uniformity to the fat, oil or margarine.

Costs

The cost of fortification with the oily vitamins is low. In current US\$, the cost of fortifying a margarine at 33,000 IU/kg vitamin A (as retinyl palmitate), and 3,300 IU/kg vitamin D is approximately \$0.003/kg when a vitamin A/D₃ blend is used. If vitamin A were added alone, the cost would be approximately \$0.0018/kg. Fortification may require modest changes in packaging, labeling and handling.

In current US dollars, the cost of fortifying a margarine at 33,000 IU/kg vitamin A would be approximately \$0.0018/kg.

Benefits of Fortifying Fats and Oils

One of the pioneering studies showing the benefits of adding vitamin A to margarine was performed in Canada in the mid-1940s. In this trial, vitamin A-fortified margarine and enriched white flour were used in Newfoundland in 1944 and 1945. Margarine was fortified at 45,000 IU per kg resulting in a per capita intake of 1,575 IU per day. Because of this fortification program, vitamin A status markedly improved, as indicated by biochemical markers.

Recently, a collaborative project was conducted in the Philippines that demonstrated that fortification of margarine with vitamin A could significantly reduce xerophthalmia due to vitamin A deficiency. At the beginning of the study approximately 25-30% of the children had low serum retinol levels. After six months, only 10% of the children in the fortified margarine group had low serum retinol levels, whereas in the control group, 28% had low levels.

Tackling Micronutrient Malnutrition: Two Case Studies in India

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Abstract A hydrogenated vegetable oil, *vanaspati*, is an inexpensive substitute for ghee, or clarified butter. *Vanaspati* is used as a cooking oil medium by 90% of all households in India. Fortification with vitamin A became compulsory in 1953, and today, the one million tons produced annually contain 25 IU/g of vitamin A. In India, the average consumption of *vanaspati* is 3 grams per day. This level of fortification provides 4% of the established RDA. A major producer of vitamin A-fortified oil reports costs at 90 rupees per ton or .3% of the total product cost. This presentation covers two case studies: vitamin A fortification of *vanaspati* and iodization of salt. Both examples are intended to illustrate the modality by which the problem of micronutrient malnutrition in the masses is diagnosed and by which viable solutions are found.

VITAMIN A FORTIFICATION OF VANASPATI

Historical Background

The term *vanaspati* means, literally, lord of the forest and signifies that it is a vegetable oil product. *Vanaspati* was developed as a substitute for the expensive butter fat known locally as *ghee*. It was introduced in India after World War I by imports from Europe. In 1928-1929, 23,000 tons of *vanaspati* were imported. The first *vanaspati* factory was established in India in 1930 by Indian Vegetable Products Limited, Bombay, followed by Ganesh Flour Mills, The Hindustan *Vanaspati* Manufacturing Co. Ltd. and Tata Oil Mills Co. Ltd. (now Hindustan Lever Limited) in 1930, 1932 and 1933 respectively.

With government incentives, the industry prospered, and by 1935 imports were negligible. At present about 0.9 million tons of *vanaspati* are being produced in India annually.

Vegetable Oil Product Control Order

Prior to 1947, there was no centrally administered law controlling the manufacture and quality of *vanaspati*. In 1947 the government formulated the Vegetable Oil Products Control Order under the Essential Supplies

Act, which was later, on January 26, 1955, brought under the Essential Commodities Act. Amendments to this order have been ongoing as a result of intensive interactions between industries or industry associations such as *Vanaspati* Manufacturers' Association, government agencies and nutritional bodies. Examples of amendments include raising the maximum melting point from 37° to 41°C and increasing the unsaponifiable matter content from 1.5 to 2.5% to facilitate higher incorporation of rice bran oil.

Nutritional Aspects of *Vanaspati*

In India, nutritional investigations on *vanaspati* were conducted under the auspices of the *Vanaspati* Research Planning Committee in 1946 and the *Vanaspati* Research Advisory Committee in 1947.

During the Second World War the *vanaspati* industry faced a serious problem because *vanaspati* was considered injurious to health by an important section of the public. This prompted the *Vanaspati* Research Planning Committee to plan and carry out experiments on animals and human subjects at various centres with special reference to conditions prevailing in India. A comparison was made between raw, refined groundnut oil, *vanaspati* and cow *ghee*.



Vanaspati (left) was fortified with vitamin A in order to make it nutritionally comparable to the more expensive butter fat known as ghee.

These studies showed that *vanaspati* is perfectly harmless and that in nutritional value it resembles the edible oils from which it is made. *Vanaspati* in those days was made chiefly from groundnut oil, whereas today a score of edible oils are permitted for use in *vanaspati*.

The Vitamin A Story

A second aspect of the poor nutritional standing of *vanaspati* in the 1940s was that, unlike *ghee*, it did not contain vitamin A. It is a fact that *vanaspati* manufactured prior to 1950 did not contain vitamin A, because vegetable oils used in its manufacture did not have vitamin A and the only external, oil-based source of vitamin A available was marine oils. These were not incorporated because it might offend the socio-religious beliefs of the consumer. When synthetic vitamin A was produced in 1950 from lemon grass oil (vegetable base), it attracted the attention of the Ghee Adulteration Committee, which recommended in November, 1952, that *vanaspati* should be fortified with synthetic vitamin A in order to increase its nutritional value and make it comparable to *ghee*. A similar recommendation was also made by the Nutrition Advisory Committee of the Indian Council of Medical Research in 1953.

Even prior to this, in 1951, the Vegetable Oil Products Controller had specified that manufacturers of *vanaspati* making a claim that their product is vitaminized should declare the names of the vitamins on the label

and that the minimum quantity added should be not less than 300 IU/oz (10.6 IU/g) of vitamin A and 50 IU/oz (1.76 IU/g) of vitamin D. The optional addition of vitamin A became obligatory from October 1, 1953, and the minimum level of addition of vitamin A at the time of manufacture was raised to 700 IU/oz (about 25 IU/g) from May 1955. This level of vitamin A in *vanaspati* seems to have been fixed to make it comparable to *ghee*. This level holds even now. Although not compulsory, many manufacturers, including Hindustan Lever Ltd., also incorporate vitamin D (2 IU/g) in *vanaspati*.

Vitamin A Availability

Vitamin A is present in animal foods such as butter, *ghee*, whole milk, egg yolk and fish liver oil, but not in vegetable foods. However, provitamin A, β -carotene, is present in many vegetable foods and also in some vegetable oils, especially crude red palm oil. About 800 micrograms β -carotene is present in 1 g of red palm oil. Most of the carotene in oils gets destroyed during processing to *vanaspati*.

The RDA for vitamin A in India is 600 micrograms, or about 2,000 IU per day for an adult weighing 65 kg; 950 micrograms/day for lactating women; and 350-400 micrograms/day for children.

One report mentioned that the supply of vitamin A as well as other nutrients such as vitamin C, riboflavin, calcium and fat was deficient by 61 to 94% in India. A case study of some villages in the Madhya Pradesh State showed that in the study region the average per capita per day availability of vitamin A was 790 micrograms. This was higher than the RDA, although the range varied between 140 and 2,233 micrograms. In about two-thirds of the villages, vitamin A availability was found to be below the regional average.

It was also reported that vitamin A deficiency was a major problem affecting young children. To tackle this, two approaches were advocated. One approach was to educate mothers to feed children with green leafy vegetables and yellow fruits to provide β -carotenes and the other was to administer a massive dose of vitamin A, i.e. 20,000 IU, in a spoonful of groundnut oil every six months. The second approach, supposedly practiced in several states, was based on the fact that vitamin A can be stored in liver and utilized slowly over time.

Fortification of *vanaspati* with vitamin A, a compulsory factor for all manufactured *vanaspati*, also contributes to the supply of this vitamin to the population.

One must consider the availability of vitamin A at consumption level and the consumption of *vanaspati* by different sections / regions of the population.

Vitamin A Intake Through Vanaspati (Per Person)

Regions	% RDA		
	Urban	Rural	Total
North	21.0	1.4	6.3
East	12.0	0.5	2.5
West	9.5	0.9	3.7
South	4.4	0.4	1.5
All India	12.0	0.8	3.7

Vitamin A Stability

Although 25 IU/gram of vitamin A is added during manufacture, there is bound to be loss of the vitamin during storage and usage. Studies conducted in 1956, including that by Hindustan Lever Ltd, showed that vitamin A loss was about 25-30% during storage and 28-32% for six months in sealed containers. Loss is highest during shallow frying at 220°C, lower during deep frying at 200°C and negligible during simmering. It was also observed that loss of vitamin A from *vanaspati* was less compared to *ghee* under the experimental conditions.

If one assumes that *vanaspati* is consumed within two to three months of manufacture, nearly 85-90% of the originally added vitamin A will be available during consumption. It is a general practice by the industry to incorporate an excess of vitamin A during manufacture to make up for storage losses. So, one can assume that 25 IU per gram of *vanaspati* is available at the time of consumption. The method of cooking could, however, result in negligible to significant losses of the vitamin. This is not taken into consideration in the following calculation for supply of vitamin A through *vanaspati*, as no clear-cut segregation of the *vanaspati* usage for different types of cooking is available.

Consumption Patterns

For a population of 900 million consuming 0.9 million tons of *vanaspati*, the average consumption is 2.7 g or approximately 3 g/day. Assuming 25 IU/g vitamin A is available at consumption, the average contribution from *vanaspati* will be about 75 IU/g or 3.8% of RDA (2000 IU or 600 micrograms). The average *ghee* consumption is of a similar order and can contribute to approximately the same level of vitamin A. However, a survey indicated that the average *vanaspati* consumption is higher at 10 g/day in the higher income group, making vitamin A availability 250 IU or 12.5% of RDA. A distribution of the *vanaspati* consumption by region indicates that the urban population consumes between 3.5 and 17 g/day; the South urban population consumes the minimum amount and the North urban region consumes the maximum amount. The vitamin A supply through *vanaspati* for the urban population varies between 88 - 425 IU per day per person or 4.4 to 21% of RDA. The rural population consumes very little *vanaspati* (0.3 to 1.1 g/day) and obtains negligible levels of this vitamin through *vanaspati*.

The data suggests that the contribution from *vanaspati* of vitamin A supply is reasonable in the urban population and negligible in the rural population. The situation could change in the future for the better in the rural population as the per capita income is showing an increasing trend and could result in higher consumption of *vanaspati*. This is aided by the fact that *vanaspati* is now sold in smaller 50 and 100 g affordable packs.

Vanaspati Manufacturers' Association of India

VMA provides technical support and evidence that will help in enactment or amendment of laws for the growth of the industry. For example, the generation of stability data on vitamin A helped explain the availability of the vitamin at the time of consumption. The principal objectives are:

1. Promoting and protecting the *vanaspati* business;
2. Promoting and organizing scientific research to advance the industry;
3. Initiating and promoting with public authorities the passage of laws, amendments and administrative regulations to support the industry's growth;
4. Enlightening the public on matters regarding the industry.

Looking Forward

Restrictive laws, for example, the one stating that all the oils used for manufacture of *vanaspati* except sesame oil (which is post dosed) must be hydrogenated or that addition of useful additives such as vitamin E is not permitted, have stood in the way of innovation of the product. Hindustan Lever Ltd., through VMA, has taken a strong initiative to collaborate with government authorities and nutritional laboratories to remove the restrictive laws. There has been considerable progress in the last few years in this area, which has resulted, for example, in the introduction of interesterification as an optional process step which allows development of higher PUFA (polyunsaturated fatty acid) products. Even use of unhydrogenated oils and incorporation of useful additives such as vitamin E acetate, antifoaming agents, etc. are under consideration. These modifications could result in widening the array of *vanaspati* type products which are nutritively better and cater to the various performance needs of the consumer. Hindustan Lever recently has launched Dalda Manpasand as an experimental product with special sanction from authorities. The product is nutritively superior to standard *vanaspati* in having no less than 1% trans fatty acids and higher polyunsaturated fatty acids. The product has a pourable consistency which is considered to be a plus by the consumer for many applications.

The current liberal and positive attitude of government authorities in understanding the needs of the *vanaspati* industry and the consumer augurs well for product innovations which would result in more nutritious and performance-oriented products. The small affordable packs recently introduced should also extend the reach of these products to low income groups and improve the supply of some nutrients.

IODIZATION OF SALT

Iodine Fortification of Salt

Iodine, an essential trace element, is an important constituent of thyroid hormones, which are necessary for normal growth and development. Iodine deficiency disorders (IDD) range from abortions, still births, cretinism, and goitre to impaired mental function and retarded physical development.

IDD is a global health problem affecting 118 countries including India. About 160 million persons are at

the risk of IDD in India, including 54 million with goitre, 6.6 million with mild neurological deficits and 2.2 million with cretinism. No state in the country is free from IDD, although it is more prevalent in the North, Himalayan and sub-Himalayan plains.

The recommended daily intake of iodine (WHO / UNICEF / ICCIDD, 1993) is 150 micrograms for adults and varies between 40 to 200 micrograms for infants and lactating or pregnant women.

The Kangra Valley study in 1956-62 proved the efficacy of iodized salt for the control of IDD. The National Goitre Control Programme initiated in 1962 to supply iodized salt in endemic areas had only limited success because of inadequate production and supply, ignorance in the community of iodine deficiency, lack of coordination of involved authorities, and other factors.

One estimate sets the requirement of salt per individual (including animals) at 6 kg per annum, necessitating a total of about 5.6 million tons of salt. More than 60-65% of this is now produced as iodized salt and the capability exists for further production.

Government Policy and Manufacturers' Initiative

In 1984, through the National IDD control program, the Government of India adopted the policy of universal iodization of salt by 1995. The National Nutrition Policy set a goal of reducing IDD to less than 10% by the year 2000.

Ban on the sale of non-iodized salt by state governments to promote demand for iodized salt is an important step in the universal iodization of salt. It is believed that almost all the state governments have issued notifications of this by now, although this needs confirmation.

In addition to the government initiative, the salt commission's office has also played a pivotal role in extending the fortification of salt with iodine. This office organizes and coordinates the development of the salt industry, improving manufacturing methods and overseeing the distribution of salt throughout the country. The success so far achieved is no small measure, also due to the cooperation and collaboration of the salt producers who understand the importance of eliminating IDD and of their role in improving public health.

Salt Production

Before 1983 iodized salt was confined to the public sector. Presently, there are about 9,000 common salt producers in India, of which 90% are reportedly in the

With more entry from new manufacturers in production of salt, the promotional attitude of government, and the Salt Commission, it is expected that the target of universal iodization of salt will be reached.

private sector. There are 500 iodization plants and nine laboratories for control of quality.

Salt is produced using sea brine, sub-soil brine and lake brine. Less than 10% is mined. Iodization generally is carried out by spraying with potassium iodate solution and packaging. It is reported that 20% of edible salt consumed in India is packed in 1 kg polythene bags. Five years ago virtually no salt was packaged in this way. This is a positive development, as it will help to increase consumer brand loyalty, quality control and could pave the way for fortification with other useful micronutrients such as iron. The Indian food industry reportedly is also using iodized salt in products, which is a welcome sign.

Stability of Iodine in Salt

A study conducted by the National Institute of Nutrition (NIN) showed that 25-30% of iodine was lost in three months and 40-60% in one year under standard conditions. A more recent study estimated the loss of iodine at 17% in three months and 36% in six months.

The Prevention of Food Adulteration Act (PFA) specifies a level of 30 ppm max. of iodine during manufac-

ture and 15 ppm min. at consumption. Contradictory reports indicate that 72% of iodized salt had adequate iodine levels or that 61% of the salt samples contained less than adequate levels (15 ppm) of iodine. The stability of iodine in salt appears to be variable, and it is important to ensure that the minimum level of iodine is available to the consumer. Suggestions have been made by WHO to raise the fortification with iodine to 50 ppm. Even assuming that all of this is available and the salt intake is 10 g per day per individual, the total daily iodine intake will be less than the maximum safe limit of 1,000 µg.

Efficacy of Iodized Salt: NIN Experience

This study involved the supply of salt fortified with iodine (150 ppm) or iron (10 mg) per 10 g salt or a combination of the two. Stabilizers incorporated included calcium carbonate (0.63 g/kg) for iodized salt and sodium hexametaphosphate (10 g/kg) for iron-fortified or iron/iodine-fortified salt. At the end of two years, the results showed that all the fortified salts were stable and acceptable to the community. No undesirable effects were noticed. The prevalence of goitre decreased significantly. The results indicated that use of stabilizers is safe and effective in the control and prevention of IDD.

Future Outlook

With more entry from new manufacturers in production of salt, the promotional attitude of government, and the Salt Commission, it is expected that the target of universal iodization of salt will be reached. With the increasing availability of small-pack iodized salt and the organization and amenities to produce the fortified salt, it will not be long before salt is looked upon as a medium to enhance the supply of other micronutrients such as iron and other trace minerals. Hindustan Lever is a recent entrant in this field and has plans to produce about 0.1 million tons of fortified salt in 1997. The company is keenly investigating the possibility of fortification of salt with other micronutrients.

A Case Report on the Fortification of Margarine with Vitamin A: The Philippine Experience

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Abstract *Non-refrigerated margarine is consumed throughout the Philippines, including the lowest socioeconomic groups. Thirty-nine percent of children consume this margarine. A concerted effort of NGOs and academic institutions motivated the Philippines' largest margarine manufacturer to develop a product fortified with vitamin A. Among children who consume the fortified margarine, tests indicate 63% fewer children with low serum retinol. After a nationwide launch of the product, sales increased 26%. A classic win/win for industry and public health.*

Introduction

Vitamin A deficiency (VAD) is a public health problem in the Philippines, affecting mostly preschoolers. This was confirmed in three national nutrition surveys which showed that the prevalence of subclinical VAD among preschoolers is about 35% and is highest in pockets of urban poor and poverty-stricken rural areas in most regions of the country. The prevalence of subclinical VAD is also increasing among children above age seven.

The major cause of VAD in the Philippines is the low intake of vitamin A-rich foods compounded by the low intake of fats and oils and the high prevalence of infections and parasite infestations. According to the latest nationwide study (1993), the average vitamin A consumption of the population is about 74% of the RDA in the rural and 88% in the urban communities. However, a study on the intake of vitamin A and fortifiable foods in depressed households (1992) showed that all groups have vitamin A intakes below their recommended dietary allowance (RDA): lactating mothers, 28%; pregnant women, 47%; and preschool children, 73%.

The Philippines has adopted, in varying degrees, three alternative forms of intervention to the VAD problem: community-based vitamin A supplementation, which has been conducted yearly for the past four years; food fortification or the addition of vitamin A and other needed nutrients to food; and nutrition education with home food production. Of the three strategies, food for-

tification proved to be the most cost-effective in the prevention and control of VAD.

More than 20 years ago in Cebu, Philippines, a collaborative effort of academic, government and nongovernment organizations resulted in a first attempt at vitamin A fortification. The commonly consumed monosodium glutamate (MSG), a condiment centrally produced by Union Chemicals, was fortified with vitamin A. However, the fortified MSG did not make it into the market despite the successful field trial because of the organoleptic change brought about by the fortification process. Thus, an alternative food vehicle for vitamin A fortification was sought.

Margarine

The search for a suitable, centrally produced fortification vehicle that is frequently consumed or has a high potential for wide consumption, especially by the poor or high-risk groups, finally led to *Star* margarine. This hydrogenated margarine product, which requires no refrigeration, has been popular in the Philippines since 1931, even prior to the advent of electricity in most parts of the country. With ingredients approved by the Bureau of Food and Drugs of the Department of Health, the product has a fat content of 88%, consisting of a blend of coconut oil and hardened palm oil. The rest is skimmed milk and water. The margarine is enriched with vitamin B₁ (thiamine), D₃, and beta-carotene which serves as the colorant that provides the deep yellow color.

A nationwide market survey (1988) conducted by the manufacturer revealed that the margarine was used mostly as a spread on bread (88%) and rice (28%), also for frying (23%), sauteing (11%) and other cooking functions. It was consumed by the large majority (94%) of the population, mostly from the D and E economic classes (89%), followed by the A, B and C classes (11%), with more users from the rural than from the urban areas. Among children, the most numerous consumers (37%) of the product were those 12 years old and below. An earlier study on fortifiable food stuffs conducted in Cebu revealed that the margarine was consumed by 39% of children below six years old.

An NCP study (1992) on margarine consumption at the household level in six villages showed that almost 95% of the households were using the margarine. The product was mostly bought in public markets (53%) and in village variety stores (31%), usually in 100g and 250g canisters. Since the margarine is non-refrigerated, it was usually stocked at home, constantly available for use as toppings, spread on bread, and as an ingredient for cooking.

Initial Advocacy

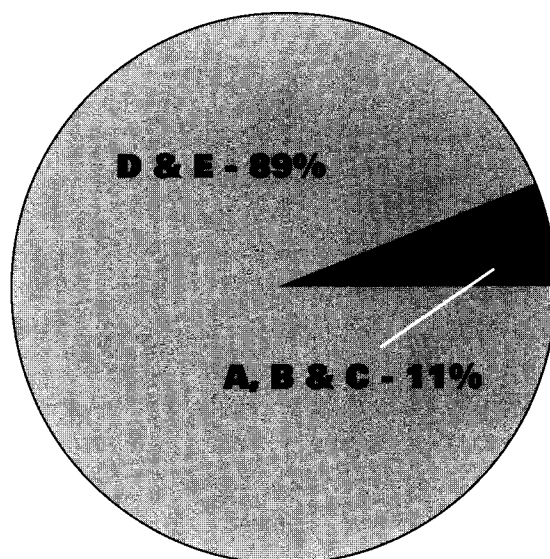
Advocacy of food fortification was first brought to Procter & Gamble (P&G) Company in Cincinnati, Ohio, U.S.A. in 1991 by Dr. Alfred Sommer, dean of the Johns Hopkins University School of Hygiene and Public Health. Dr. Sommer was a guest lecturer at the company when he learned about its Philippine product, *Star Margarine*.

On his trip to Manila, Dr. Sommer met with officials of the Philippine branch of the company about the possibility of fortifying the product with vitamin A. Referral was made to the NCP for it to explore ways of undertaking the project. The officials wanted to maintain the leadership of the product in the industry which was then controlling 94% of the market for non-refrigerated margarine. They also wanted to further improve the margarine in terms of nutrient content.

The discussion brought up two options. One, which was initially favored by the Philippine manufacturer, was a quick feasibility study on the increase in the amount of vitamin A in the product followed by laboratory tests on the retention and stability of vitamin A in margarine. Should the results of the study be acceptable, the fortified product could then be immediately launched in the market.

The other option was a retention and stability study followed by a field trial to assess the effects of consuming

Socio-Economic Distribution of Margarine Consumers



Hydrogenated margarine is consumed by a large majority of Filipinos, estimated at 94%. Among these margarine consumers, it is used much more widely by the lower economic classes (D and E) than by the upper classes (A, B and C).

a hydrogenated, vitamin A-fortified margarine not requiring refrigeration on the vitamin A status of preschool children. This would mean the extension of the study from six months to one year, with added financial and time constraints. The evident advantage, however, would be the better acceptability of the product as beneficial to the health of the people, particularly those at risk of micronutrient deficiencies. This option was finally adopted.

Stability Study

The study on the stability of beta carotene and vitamin A (retinol palmitate) added in the fortification of non-refrigerated margarine was conducted in late 1991 in the manufacturer's laboratory in Miami Valley, Cincinnati, Ohio, USA. Results showed vitamin A retentions of 107%, 87% and 58% after one, four and eight months of storage. The percentage of vitamin A recovery after heating the fresh margarine at 212°F for 15 minutes and 350°F for 5 minutes was 97% and 83% respectively, indicating good thermal stability.

Field Trial

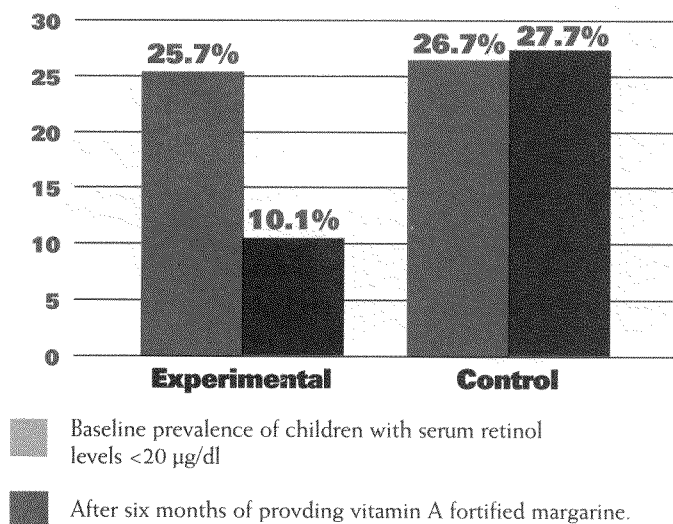
The vitamin A-fortified margarine used for the field trial contained 862 µg retinol equivalents. This included 108 µg RE from beta carotene used as a colorant in the mar-

keted margarine plus 754 µg added as retinyl palmitate per 30 g or 2 tbsp, namely 28.8 µg RE per g, providing ~230% of the Filipino recommended dietary allowance (FNRI, 1989). It was estimated that this level of vitamin A would provide ~100% of a child's needs from a 1-2 tbsp serving after accounting for losses related to storage, handling and food preparation. The vitamin A-fortified margarine also contained 6 mg thiamine (vitamin B₁) and 100 µg cholecalciferol (vitamin D₃) per 30 g serving as part of the standard, marketed product.

After the stability study, a double masked randomized community trial commenced in 1992. The field trial assessed the effects of non-refrigerated, vitamin A-fortified margarine consumption on the vitamin A status of children three to six years of age in rural Silang, Cavite in Southern Luzon, Philippines. Two forms of *Star* margarine were prepared and coded for the trial: a vitamin A-fortified and a non-fortified form. They were identical in color, smell, taste and external packaging except for their labelled codes. Six villages were randomly assigned for children to receive each week for six months either vitamin A-fortified (n=353) or non-fortified (n=350) margarine (250 g per week or about 2 tbsp daily). The vitamin A status (serum retinol, xerophthalmia and conjunctival impression cytology) of the children was assessed at baseline and follow-up.

The daily margarine intake per child averaged 27 g in the experimental group and 24 g in the control group. After six months, mean serum retinol increased from 26.4 to 28.8 µg/dl in the experimental group but decreased from 26.6 to 25.1 µg/dl in the control (P<0.001 at six months).

Impact of Fortified Margarine on Low Serum Retinol



The prevalence of low serum retinol (<20µg/dl) decreased from 25.7 to 10.1% in the experimental group but remained unchanged at 26.7% to 27.7% (P<0.01 at six months) in controls. At follow-up, no experimental children had developed xerophthalmia but 1.4% and 1.8% of controls developed night blindness and Bitot's spots, respectively. There were no differences in the conjunctival impression cytology between groups.

The field trial showed that six months daily consumption of margarine with high vitamin A fortification can reduce the prevalence of low serum retinol levels among children. Average retinol levels increased despite relatively high average levels at baseline. The virtual elimination of new cases of xerophthalmia in the experimental group, in contrast to those in the control group, attested to the effectiveness of vitamin A-fortified margarine in improving nutritional status.

Local and International Collaboration

This study, from the initial idea to its design and implementation, provided an opportunity for academic, public health, government and food industry partners to work together toward solving a common nutritional problem.

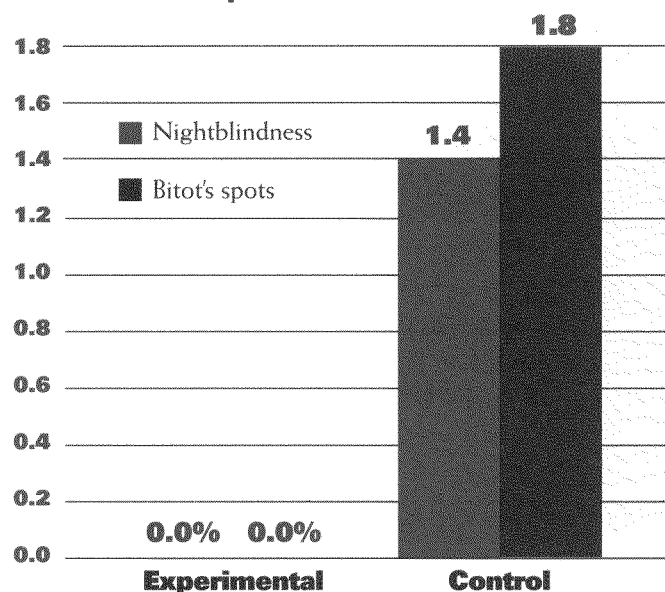
The manufacturer provided financial support in the conduct of the study with the NCP as principal investigator. NCP shared some of the financial costs as well as the logistics services not covered by funding from the manufacturer. Johns Hopkins University gave its full support through researchers assisting in the research design and in the statistical support.

The initial plan was to develop an in-country capability for biochemical assessment of vitamin A through the high performance liquid chromatography (HPLC) method. An academic institution which could be assisted by Johns Hopkins was preferred. To start with, Johns Hopkins sent an HPLC expert who conducted training for the staff of the Department of Biochemistry of the University of the Philippines College of Medicine and of the Food and Nutrition Research Institute.

As the plan was developing, the Philippines was beset by a power crisis with daily power failures. A collaborative arrangement was made to have the serum retinol analysis by HPLC method done at the Institute of Nutrition at Mahidol University in Salaya, Thailand. The offshoot was a regional cooperation for biochemical analysis between the two institutions.

The Department of Epidemiology and Biostatistics of the UP College of Public Health conducted the statistical analysis and interpretation of the results of the trial.

Incidence of Xerophthalmia



At follow-up, no experimental children had developed xerophthalmia but 1.4 % and 1.8% of controls developed nightblindness and Bitot's spots, respectively.

The Philippine Government, through the Department of Health, fully endorsed the project.

Report and Recommendations

The NCP reported the results of the field trial to the manufacturer with the following recommendations:

- Increase the vitamin A content of the margarine from 262 to 375 RE per serving (15 g) to provide 100% of the RDA of three-to-six year old children for vitamin A per serving of margarine. This would allow the highly bioavailable fortified margarine to more or less fill the consumption gap for vitamin A even if not consumed daily.
- Keep the fortified product affordable to low-income households to increase its consumption. The added cost of fortificant alone was quite minimal: P0.16 (US \$0.01) per 100 g of margarine or P0.024 (US \$0.001) per serving (~ 15 g).
- Introduce a new container size (sachet) of the product, with a capacity for one serving (~ 1 tablespoon or 15 g), the smallest and the least priced among the product's sizes. This would increase the accessibility of the product to more people, particularly to groups most at risk.

Program Scale

The manufacturer adopted the NCP recommendations and immediately launched the vitamin A-fortified margarine in the market in various content sizes, the smallest of which was a 15-gram sachet costing only P2.00 (US \$0.076). The sachet was sold mostly in small village variety stores and in public markets, thereby reaching more of the poorer segments of the population. Since the margarine could be stored without refrigeration, its 100-gram size has been widely available at P10.00 (US \$0.37) per cannister.

The product received strong promotional support which started with a social marketing campaign during the field trial to disseminate information. This was followed by 30-second radio and TV plugs on the importance of vitamin A to the human body (without mention of the product) and culminated in a full-scale product advertising campaign during the market launching. Three months after the launching, sales were reported to have increased by about 20% over the same period in the preceding year.

Since the fortification of the margarine with vitamin A, five new margarine brands have emerged in the market, all of them enriched with vitamin A. A recent market survey conducted by the manufacturer showed that the consumption of *Star Margarine* among the D- and E-economic classes increased from 89% in 1988 to 91% in 1996 despite the presence of five lower-priced margarine brands in the market, with price differences ranging from P2.25 (US\$0.08) to P0.85 (US\$0.03). However, the consumption of *Star Margarine* among the ABC class decreased from 11% in 1988 to 9% in 1996.

The volume of *Star Margarine* production in 1993, the year of the launching of the fortified product, was 4 million kilograms. In 1996, or three years since the launching of the fortified product, the volume of *Star Margarine* production increased to 5 million kilograms. This figure indicates a 25% increase in production volume despite the transition period due to change in ownership.

Official Recognition: The Sangkap Pinoy Seal

The Department of Health (DOH), in an unprecedented move, allowed a stamp of recognition with the words "Accepted by the DOH" to be placed on the label of the product, together with a testimonial in fine print: "The only margarine clinically tested by the NCP."

From this initial DOH stamp evolved the official mark of recognition called the *Sangkap Pinoy* seal. *Sangkap Pinoy* (literal translation: Filipino or indigenous ingredi-

ents) was the term initially applied by the DOH to the observance of National Micronutrients Day, popularly known as *Araw ng Sangkap Pinoy* or ASAP in short, as a rallying cry in the campaign against micronutrient malnutrition. The *Sangkap Pinoy* seal is now stamped on fortified food products which meet the high fortification standards set by the government. After *Star Margarine*, the list of product-recipients of the seal now includes weaning food, noodles, sardines and fruit juice.

While the seal was initially questioned by certain quarters on ethical grounds, the DOH has affirmed that the *Sangkap Pinoy* seal is a certificate that the product is properly fortified and has been scientifically tested. The seal also serves as a guide and a protection to consumers. On its part, the DOH has undertaken a multi-media campaign to generate awareness of the *Sangkap Pinoy* seal and its importance in promoting food fortification as a major strategy in the national nutrition program.

The *Sangkap Pinoy* seal, however, can be vulnerable to certain forms of abuse by food manufacturing companies and advertising agencies. Food products that are hardly selling or are categorized as "empty calories" can be conveniently fortified with a nutrient to qualify for a *Sangkap Pinoy* seal, which can help increase sales. A possible trend could be the proliferation of such processed food products dignified with a *Sangkap Pinoy* seal and preferred by consumers over other more nutritious food items like milk and eggs. Periodic and careful monitoring of products granted the *Sangkap Pinoy* seal is an urgent concern as well as the enforcement of a quality assurance system by the government.

Fundamental Considerations

Among other lessons posed by the *Star Margarine* fortification project, a few considerations stand out:

- The principal success of this food fortification project is that it has gone to scale and is now part of the national nutrition program. This success, however, is greatly dependent on the extent to which the food manufacturing sector is willing to cooperate or allow the use of its resources for the program, as well as on the collaboration of academia and the government. At the same time, the manufacturer's participation in the program

offers them a clear economic benefit since the nutrients added through fortification would considerably increase the social and commercial value of their products.

- The technology of adding a synthetic vitamin A to an oil-based product is feasible. The fortificant is substantially stable in storage and in high temperatures as well as in the presence of other synthetic nutrients, namely vitamins B₁ and D₃. Above all, the vitamin A in the margarine product is bioavailable and effective in improving the vitamin A status of young children.
- Since their acceptance of fortification would be supportive to the solution of a national problem, the food manufacturers deserve every encouragement they can get. A major incentive to them would be strong national policy support and an executive order from the Office of the President directing pertinent instrumentalities of the government to provide support to the manufacturers. This approach, rather than legislation, would facilitate fortification and enhance the population's consumption of fortified foods.
- Food staples are generally ideal fortification vehicles, but not all staples can be fortified with satisfactory results. Products with the next highest potential as fortification vehicles would be those that traditionally reach poor and high risk groups, those that are culturally acceptable as household food items, and those that are consumed by large (including poorer) segments of the population. In this regard margarine, which has long been part of the diet of the poor, also provides for the vitamin A-enhancing quality of fats and oils. It can thus play a key role in diet modification, one of the three basic strategies against micronutrient malnutrition.

Continued Commitment

Years later, the ownership of *Star Margarine* changed. The margarine brand is now owned by Philippine Dairy of San Miguel Corporation, the biggest food manufacturing company in the country. The new owner took over the commitment of the previous one to maintain and strengthen the high-quality fortification standards of the margarine.

Dairy Products



Fortification of Dairy Products with Micronutrients to End Micronutrient Malnutrition

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Abstract *Since they contain a fat component, milk and its derived dairy products have been utilized in developed countries as carriers for vitamins A and D for some time. As fat is removed from much of the milk consumed throughout the world, important nutrients, including vitamin A, are lost. In this case, fortification becomes critical. Recent advances are developing cost-effective processes to add iron to cheese, milk and yogurt. In most cultures, fluid milk is used predominantly among children and mothers, the most important risk groups for micronutrient malnutrition.*

Introduction

Researchers have reviewed several measures of nutritional effectiveness for the nutrients provided by dairy products. They found several key nutrient contributions from the consumption of dairy foods in a 1984 food survey conducted in the United States. Calcium and phosphorus in dairy foods were reported to provide 75.8% and 35.8% of the total calcium and phosphorus in U.S. diets. Other nutrients that were found to be contributed by dairy foods in appreciable amounts were: 34.7% of riboflavin, 20.4% of protein, 20.4% of vitamin B₁₂, 19.1% of magnesium and 11.5 to 11.7% of vitamin B₆, vitamin A and fat. Each country that is considering the use of dairy foods for micronutrient fortification needs to understand the dairy product consumption patterns of their target groups.

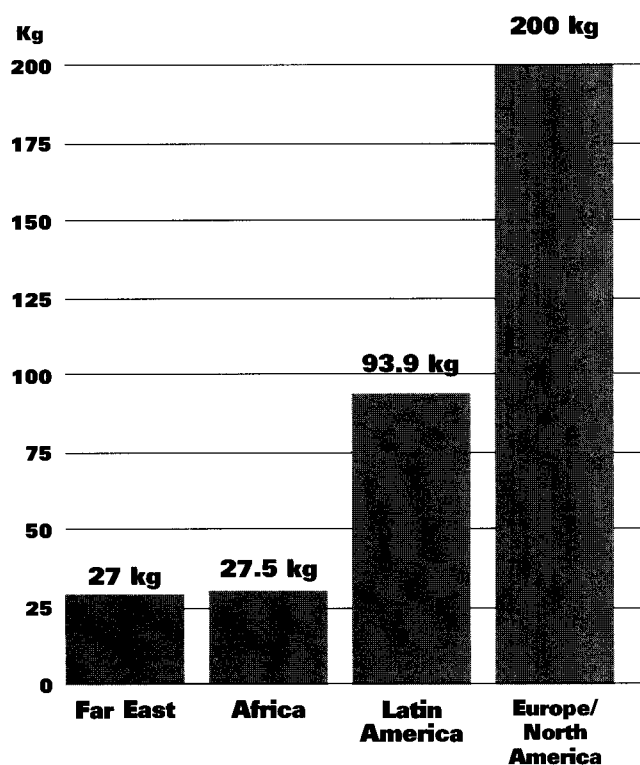
Milk makes a significant impact on the nutritive value of a diet when the primary nutrients provided by fluid milk are evaluated on the basis of nutrient density. The nutrient density measure used for comparison was the reference daily intake (RDI) per 100 kcal versus the major nutrient components per 100 kcal (Nutrition of

Normal Infants, 1993, Micronutrients in Milk and Milk-based Products, 1989 and 21 Code of Federal Register Part 104.20, 1996). Again, the leading nutrient of significance is calcium with a nutrient density of 183 mg per 100 kcal that represents 366% of the RDI on a 100 kcal basis. Additional major nutrients of interest expressed in percentage of the RDI per 100 kcal were riboflavin at 319%, phosphorus 290%, vitamin B₁₂ at 230%, iodine at 160%, potassium at 127% and pantothenic acid at 100%. It should be noted that the iodine content of milk may vary from country to country. Iodine levels in dairy products are dependent upon the iodine added to the mineral salts and rations fed to cattle and the presence of iodine-containing solutions used in the sanitation of processing and handling equipment and even the treatment of udders before milking.

As these values show, milk provides substantial levels of key nutrients for the consumer per 100 kcal and deserves consideration as a possible vehicle for micronutrient fortification. Several target populations for the micronutrient fortification of foods are typical consumers of dairy products. Young children are com-

mon milk drinkers and have growth stages and development but are often picky eaters or have limited diets due to poverty. Young adults often enjoy ice cream, yogurt, cheeses and other dairy products in the face of limiting caloric intake or consuming unbalanced diets. Lastly, women in certain countries have definite patterns of dairy product consumption in part due to their association with children and for health reasons such as to prevent osteoporosis or to aid in bearing of children.

Annual Regional Per Capita Milk Consumption



Global Consumption

The demand for milk and dairy foods by consumers varies a great deal from region to region, with the developed countries accounting for approximately 200 kg of consumption per capita based on 1990 data. The developing countries range from 27 to 94 kg per capita consumption and are divided into traditional milk producing regions and non-traditional milk producers.

The greatest milk consumption is found in Latin America among the developing countries with an estimated 93.9 kg per capita. Latin American milk producers are sometimes found to be small-scale farmers with mixed beef and dairy herds (an estimated 60 to 80% of the farms) with some large dedicated dairy herds in many countries, such as Brazil and Argentina. Some

main importers of dairy products are Brazil and Mexico in Latin America.

Milk consumption has been moderate in African countries, with approximately 27.5 kg per capita. Africa has been found to have significant numbers of cattle, but the milk yield per cow is very low when compared to Europe and North America. Farmers in Africa also produce water buffalo milk and goat milk for consumers.

The Far East is an example of a non-traditional milk producing region, with dairy cattle subject to humid areas such as southeast Asia, southern China, southern Korea and Japan. The consumption of milk by consumers in the Far East has been reported to average 27.0 kg per capita, a very limited amount.

Several factors require consideration when one projects the future consumption of dairy products for a region or country. First, substantial economic growth has fueled the consumption of dairy products in some key Asian markets as evidenced by the growth in shipments of milk powders at rates from 10 to 14% per year with imports of approximately one billion pounds in recent years for the group of countries that include China, Indonesia, Singapore, Thailand, Philippines and Malaysia.

The trend for increased urban population growth will contribute to increased dairy product consumption. For example, several companies in Mexico have developed urban markets for cheese, yogurt and ice cream that have been made from imported reconstituted milk powders. The increased change in food preferences toward Western diets will aid the increase in consumption of dairy products. In addition, increased milk yield per cow should allow more economical local distribution of the highly perishable fresh milk products to eager consumers.

Evaluating Fortification of Dairy Products

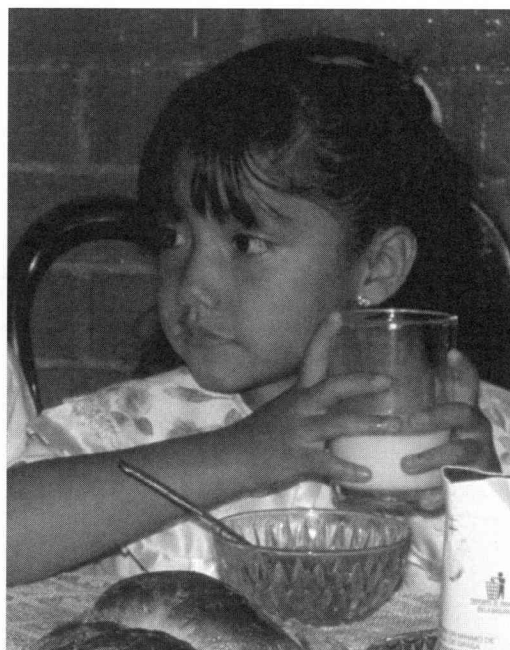
The potential impact of micronutrient fortification of dairy products on target population groups should be evaluated carefully following a series of steps. Does the target group have appreciable dairy food sensitivity? Some individuals are more likely to experience symptoms with the intake of milk and some dairy products typically caused by either milk protein allergy or lactose intolerance. Several research studies have reported that many people who may be classified as lactose intolerant can consume approximately 240 ml of milk with a meal and not suffer from adverse symptoms. Another theory is that regular intake of lactose in dairy products may help one develop increased tolerance to lactose consumption.

Milk protein allergy is fairly rare, with some estimates that only 1% to 3% of young children are affected. Milk protein allergy is a specific reaction mediated by our immune system with exposure to one or more of the cow's milk proteins.

There are a number of major issues to be addressed in the evaluation of the suitability of dairy products for micronutrient fortification include the following. The identification of the patterns of dairy product consumption and storage provides some insight into the practical selection of a dairy food for fortification. For example, if the consumers in your target group have refrigerated storage, then fresh milk and yogurt may be considered as vehicles for micronutrients. However, if the diets and customs of your target group include only the use of milk powder, you are limited to that form of dairy product.

The addition of some micronutrients may lead to the development of unacceptable flavors with certain dairy products that will not be readily consumed by the target group. One must search for compatible nutrients with the form of dairy product selected for fortification.

The processing, packaging and storage over the typical shelf-life may contribute to nutrient interactions that



The increased costs of fortification must be balanced by what the program sponsors or consumers are willing to pay for the improved nutrition provided by the dairy food.

Recommended Steps for Evaluating the Fortification of Dairy Products

- 1. Determine dairy food sensitivity of target groups including lactose intolerance issues and milk protein allergy**
- 2. Identify patterns of dairy product consumption and storage**
- 3. Develop acceptable flavors with fortified products**
- 4. Verify that added nutrients are stable and physiologically available after processing, packaging, and during shelf-life**
- 5. Prove that added nutrients do not contribute to excessive intake and possible negative effects**
- 6. Assess the increases in pricing needed to recover costs of fortification for market forms**

are not favorable for stable nutrient levels or nutrients that are no longer physiologically available for active use by the body's digestive system. One example is the degradation of vitamin A upon exposure to oxygen.

Since some nutrients can be added at levels that would on occasion lead to excessive intake and possible negative effects, careful planning should prevent this concern from becoming a reality for a target population. The fortification of micronutrients for dairy products does cost money for the ingredient and the control measures that must be taken to ensure adequate and safe nutrient delivery. The increased costs of fortification must be balanced by what the programs or consumers are willing to pay for the improved nutrition provided by the dairy food.

Fortification Levels

Several nutrients have been fortified in milk and dairy foods in an attempt to meet the dietary deficits of target groups. The addition of vitamins A and D to fluid milk, skim and low-fat milks is now regulated by several countries. Some controversy exists for the target fortification level for vitamin A for dairy products. Some food aid programs have recommended 5,000 IU of vitamin A per 100 grams of skim milk powder using the assumption

that a milk consumer would have a 40 to 80 gram per day intake. This level of vitamin A fortification would be approximately 5,000 IU per liter of reconstituted skim milk. The regulations in the United States would limit the fortification of skim milk to a label claim of 2,114 IU vitamin A per liter. The addition of vitamin D to skim and low-fat dairy foods has been claimed to have contributed to the virtual elimination of rickets for children in the U.S.A. Several northern European countries have recently recommended the fortification of vitamin D for skim and low-fat dairy products.

Consumption Patterns

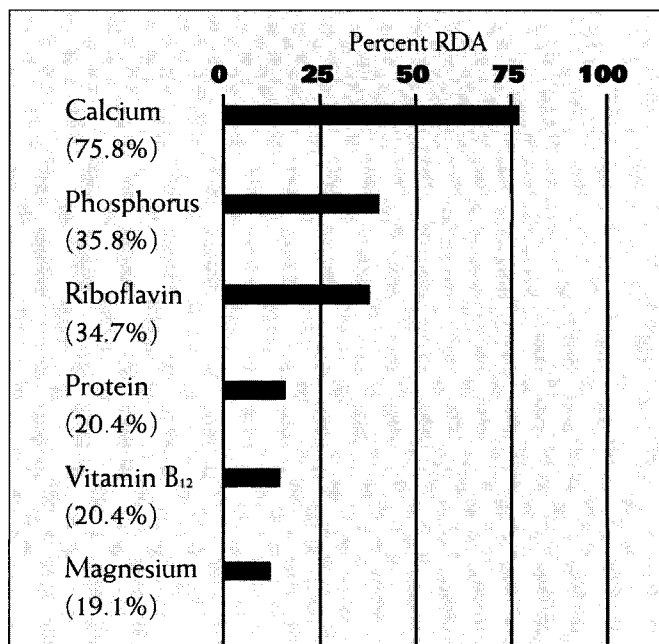
The food scientist has to plan carefully to understand the probable consumption patterns of the fortified dairy product as part of the consideration when setting a target fortification for oil-soluble vitamins. The fortification of vitamin A for Colombian milk (Institute of Family Bureau, 1985) is a good example of the importance of defining the consumption patterns. When the milk consumption was estimated based on import, export, manufacturing and other reports and calculated as food balance sheets, the country would have a typical consumption of vitamin A at 110% of adequacy. However, when an actual food survey with low-income target groups was done and the real milk consumption defined, the fortification of 4,000 IU of vitamin A per liter of milk would provide approximately 80% of the adequate vitamin A.

The Fortification Process

We will explore in detail the fortification of vitamin A to skim milk to further illustrate the fortification planning needed for the micronutrient addition to dairy products. The three most common sources of vitamin A are vitamin A acetate, vitamin A palmitate and beta carotene. The use of vitamin A acetate is widespread for spray-dried milks and common in Europe. Fortification with vitamin A palmitate is practiced in the U.S.A., even though a distinctive flavor can be detected for most fortified dairy products. The use of beta carotene is less frequent since it has a characteristic reddish color and has been reported by some researchers to have one-sixth the vitamin A potency as vitamin A acetate or palmitate. Some recent questions have been raised that beta carotene may have more vitamin A activity than previously thought.

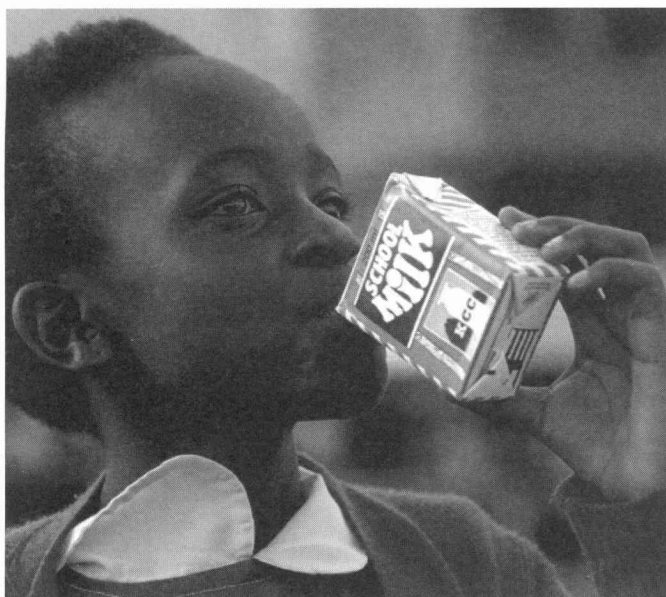
The practical perspective for vitamin A fortification includes concerns for the naturally occurring vitamin A

Typical Nutrient Contributions from Dairy Products Based on U.S. Survey



The impact of milk on the nutritive value of a diet was measured by comparing the reference daily intake (RDI) per 100 kcal to the major nutrient components per 100 kcal in a study of normal infants. Several nutrients were found to have a significant impact.

levels, correct premix handling procedures, processing and packaging interactions and shelf-life stability. Inherent levels of vitamin activity in raw milk have been found to vary seasonally with 1,400 IU/liter in summer and approximately 400 IU/liter in winter due to the exposure of the dairy cattle to sunlight and the level of carotenoids in feed. The vitamin A added to milk is typically part of a concentrate or premix that has been certified to contain a target vitamin A activity. Processors must store the concentrate away from light and heat and prevent or limit exposure to oxygen since both retinol and beta carotene have conjugated carbon double bonds that are easily oxidized. Vitamin A should be added after standardization and before homogenization and heat treatment of fluid milk, or added to the product before evaporation and spray-drying of powders. The refortification of reworked fluid milk should be carefully monitored to prevent excess vitamin A in the finished product. After the vitamin A is added to milk powders many processors will take the following steps to help ensure a long shelf life: (1) limit the water activity of the powder at drying, (2) flush the headspace of powder cans with nitrogen and carbon dioxide to limit oxygen and (3) store the fortified powder under cool



Nutrients included in the fortification of dairy products must always prove their worth in safety, stability, bioavailability and performance.

conditions. The final consideration is the selection of packaging to ensure that the product contact surface does not absorb the added vitamin A and deplete the fluid milk of this nutrient. Some researchers have reported that high density polyethylene may pose a problem.

Iron Fortification

Many food scientists have developed iron-fortified milk and dairy products that range from soft cheese, yogurts and fluid milks to skim milk powder to fulfill the promise of a complete, nutritious food. The selection of non-heme iron salts for dairy products depends primarily on the following factors. Solubility in water and

dilute acid solutions should be a factor, with the more bioavailable iron salts generally having the greater solubility properties. Ferrous sulfate is often used as an index of bioavailability to compare other salts. Some researchers have reported that ferrous fumarate, ferrous lactate, ferrous succinate and iron aminochelate have greater iron bioavailability than ferrous sulfate.

The iron content per gram of added salt is also an important factor with the group of elemental iron powders (reduced iron, electrolytic iron and carbonyl iron) having the greatest content levels of approximately 98%. In addition, some products require an iron salt that has minimal reaction with food, with ferric orthophosphate, ferric pyrophosphate and elemental iron as good selections. Lastly, the interaction with other nutrients may enhance the iron bioavailability. Ascorbic acid has typically been described as an effective enhancer of iron salt absorption as is shown for the combination of 15 mg iron/liter with 100 mg/liter of ascorbic acid. Some recent studies have proposed that long-term iron absorption as assessed by serum ferritin or hemoglobin concentrations may not be enhanced by the combination of iron salts and ascorbic acid.

Conclusion

In conclusion, selection of future nutrients for use in dairy beverages and foods must include careful evaluation of the beneficial efficacy in developing countries combined with a comprehensive assessment of nutrient interactions during processing, packaging and storage. We frequently must balance the cost of potentially useful nutrients with the benefits to the consumer. Nutrients included in the fortification of dairy products must always prove their worth in safety, stability, bioavailability and performance.

Fluid Milk as a Suitable Vehicle for Iron Fortification: The Case of Argentina

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Abstract *Despite high meat intake, iron deficiency anemia in Argentina is a major public health issue, affecting up to 62% of vulnerable groups. Moreover, fortified dry milk often does not reach infants and young children because, as in many parts of the world, families have a strong preference for fluid rather than powdered milk after breast-feeding. However, the fortification of fluid milk with iron has been hampered by issues of bioavailability and taste. Researchers and food technologists in Argentina have developed an iron-chelate and a micro-encapsulated iron compound that overcome these traditional barriers.*

Introduction

One of the most cost-effective interventions universally recognized for the prevention of hidden malnutrition is food fortification. The success of a food fortification program is based on the adequate selection of the vehicle, its economic sustainability, the legislation that regulates it, quality control, and the surveillance of both the deficiency prevalence and the pattern of intake of the fortified foods by the vulnerable groups.

Despite high meat intake, iron deficiency disorders in Argentina represent a first-order public health priority. This presentation will discuss the usefulness of milk and especially the complementation of whole milk plus bread-flour as part of a legislative proposal now being considered at the Argentinian Congress and the history of its development.

Iron Deficiency Anemia in Argentina

Argentina, like other countries in Latin America, is a transitional society. As such, large population segments presently have no major health and nutrition problems, while others suffer the consequences of overfeeding and others have relatively high morbidity and mortality rates, shorter life expectancy and nutritional deficiencies, even obvious Protein Energy Malnutrition (PEM).

Less evident, but not without importance, is the high prevalence of micronutrient deficiencies. The iodine deficiency disorders have been almost eradicated by table salt iodization. Some data strongly suggest that vitamin A deficiency could be a public health problem in Argentina, but the population surveys are scarce and this fact probably requires more in-depth epidemiological research. Iron deficiency disorders are by far the most prevalent nutritional problem now affecting Argentina. That seems to be a paradox, because our country, now and in the past 50 years, has a meat availability averaging 100 kg/person/year, which is one of the highest meat intakes all over the world.

In the past ten years there have been three population surveys that have demonstrated that the prevalence of anemia is between 25% and 62% in vulnerable groups. These surveys were funded not by the government, but by CESNI, an NGO lacking any official support. These studies also show that anemia was present at all socioeconomic levels, but with slightly lower prevalences among the more privileged. In practically all cases anemia was not severe; most infants and pregnant women had hemoglobin values between 10 and 11g/dl. The low dietary iron intake, low serum ferritins and high prevalence of elevated ZPP (zinc protoporphyrine, and index of inefficient haemoglobin synthesis) confirm the sideropenic etiology of anemia.

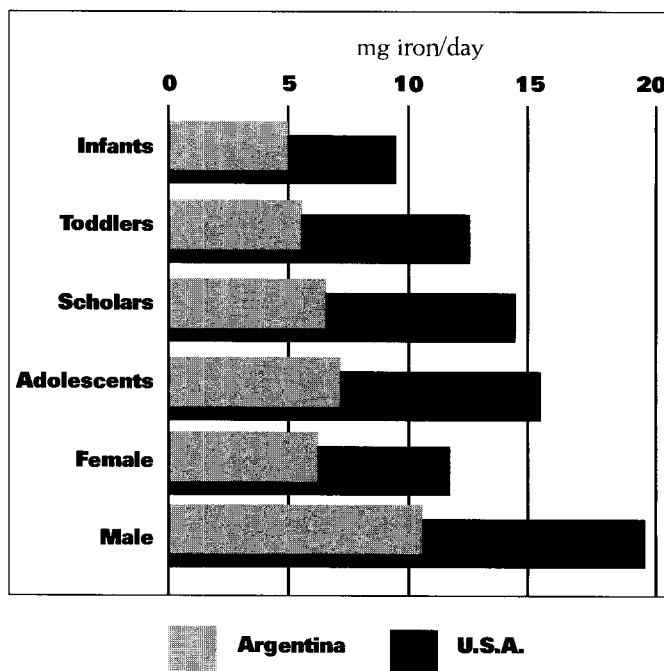
The prevalence of anemia in the earlier studies (ten years ago in Greater Buenos Aires (GBA) and Misiones Province) was almost twice that found recently in Tierra del Fuego province (TDF). Total iron intake and dietary iron density (mg iron/1000Kcal) were similar in all the studies, showing that iron intake of 90% of infants was below 11mg/day (basal requirement, considering a global iron bioavailability of 10%) and of 70% was below the requirement to prevent anemia. Heme iron intake, as percent of daily iron intake, was also similar in GBA and TDF provinces, amounting to 18% to 14%. As a result, 90% of infants in these surveys had an intake of bioavailable iron (according to the Monsen and Balintfy equation) below the 95th percentile of the requirement for absorbed iron (FAO-WHO, 1988).

A multiple regression analysis demonstrated that early introduction of unfortified cow's milk was significantly associated with the risk of suffering anemia in the earlier studies but not in the recently performed one (TDF). It is important to mention that TDF province has the best health indicators in the country, even better than those of the Federal District. There is no extreme poverty, illiteracy is nil and per-capita expenditures in social and welfare issues are also the highest. But probably the most important difference between these three studies is the fact that supplementary iron was given for a longer time in TDF than in the other locations.

Perhaps this issue of prescription and compliance of supplementary iron is related to the time elapsed between the earlier studies and the most recent in TDF. The publication of the Misiones and GBA studies produced concern among the pediatric community and health authorities. During this decade studies about developmental delays occurring in iron-deficient infants were profusely covered by the lay press, generating public concern. These facts possibly increased the prescription and compliance of supplemental iron and perhaps induced improvements in the quality of infant diets, increasing intakes of absorption enhancers (ascorbic acid) and less mate and tea (high in polyphenols) in bottles and during meals.

Despite a higher concern about anemia among the population, the prevalence in TDF was 25% and we can speculate, given its good health standards and observation of the recommendations for infant care and prevention of iron deficiency, that prevalence of anemia in infants is the lowest figure possible without food fortification programs in our country.

Iron Intake in Argentina and U.S.A.



The difference in intake between the U.S.A. and Argentina may be in large part attributable to the 24% of total iron from fortified sources in the United States. Out of a total Argentine population of 32 million, more than 4 million suffer from anemia and more than 8.2 million have depleted iron stores.

Other population studies showed that the prevalence of anemia in preschool children (11%) dropped to about half the prevalence observed in infants. Again, in all cases anemia was mild, 19% had serum ferritin below 12ug/dl and 14% had ZPP values > 100 mMol/mol Mb.

The data from anemia in non-pregnant women of fertile age is described in five studies. The earliest one was conducted in the province of Salta in the northernmost region of the country and showed a prevalence of 41%. Another study in the province of Corrientes (NE) was conducted in low-income suburbs of the city, with a high prevalence of parasitic infestation (22% of surveyed women had uncynaria), and the prevalence of anemia was 35%. But in these two studies only hemoglobin values were obtained. The study of adolescents in Buenos Aires city (mid and mid-low SEL, 1995) showed a steady increase of anemia in girls with the progression of the pubertal spurt. The prevalence of anemia at the end of adolescence in females was 18%; in males it was very low. In the study of GBA the prevalence of anemia was 25% and the iron stores (calculated according to Cook

and Finch) were <150mg in 49%, <300mg in 64% and <600mg in 81% of women. The median of iron stores was estimated at 180mg, 10th percentile was <390mg and 90th percentile, <750mg.

In the pregnant women group there is only one population survey available. In this study the prevalence of hemoglobin values below 11g/dl in each trimester was 17%, 23% and 31% at trimesters I, II, and III, respectively. Prevalences of serum ferritin values below 12 µg/l were 8, 27 and 41% in the same trimesters. Median iron intake was 8.3 (5.5-10.8 interc.rank)mg/day; heme iron intake was 0.9 (0.44-1.7) mg/day and bioavailable non-heme iron intake 0.49 (0.3-0.8) mg/day. Eighty-eight percent of women had intakes below 1mg of bioavailable iron.

In summary, the available population studies show that iron deficiency anemia is an important public health problem in Argentina, especially in infants, pregnant and fertile age women that is mainly due to a low intake of bioavailable iron and that at least in children is closely related to the early introduction of unfortified whole milk immediately after breast-feeding. The projections of these representative studies shows that out of a total Argentine population of 32 million, more than 4 million suffer from anemia and more than 8.2 million have depleted iron stores.

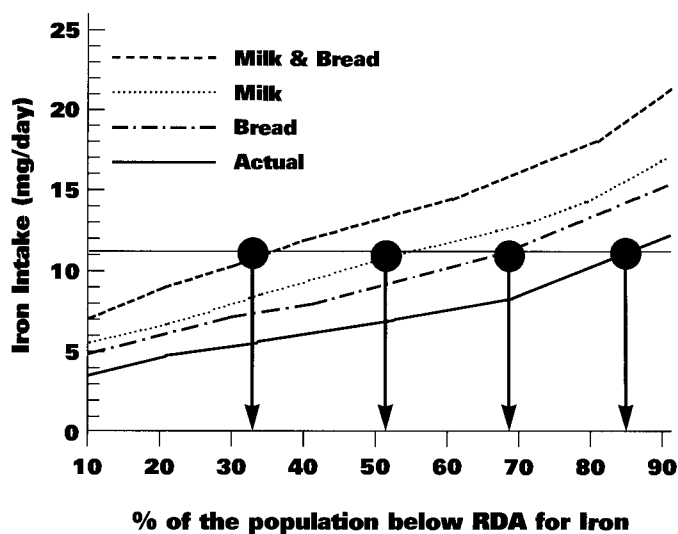
Milk and Flour as Complementary Vehicles

The adequate selection of a vehicle for fortification depends on technical issues related both to the fortification compound and to the process of fortification; the acceptability, social prestige and nutritional value of the vehicle; the pattern of intake (including socioeconomic and regional universality, availability and biologic targeting); and economic issues related to the cost of the program.

Twenty foodstuffs configure the Argentine basic food basket according to balance sheets and food recall surveys. These include bread and other foods made with wheat flour, cow meat, sugar, milk, cheese, sunflower oil, potatoes, green vegetables, rice, oranges, apples and tomatoes. From these, wheat flour and whole milk complement each other, improving the targeting of the risk group.

Despite the universal assumption that bread and milk are consumed by almost everyone, the bread and whole milk pattern of intake of infants, toddlers, school-children, adolescents and adults are quite different. As a consequence, the fractional iron intake contribution

Iron Intake Effect of Different Vehicles on Children



A computer modeling of nutrition surveys indicate the actual diet does not offer sufficient iron for nearly 90% of Argentina's children. When only fortified milk (10mg/liter iron) or only fortified bread (flour fortified to 44mg/kg) is substituted, this figure drops to 50-65%. However, both fortified milk and bread lower the percentage of children below the RDA to around 30%. The author hypothesizes both a biological and socioeconomic "complementation" of milk and bread consumption.

would be too low in a flour-based fortification program for infants and inadequate for adults in a milk-based one. But these vehicles complement each other, resulting in a significant reduction of the population below the iron RDAs.

This kind of "biological complementation" is different from a second kind based on the stratified food pattern of different socioeconomic levels. As shown by data from the Argentine permanent household survey, there is an inverse pattern of milk and bread consumption according to socioeconomic levels. In low-income families the whole milk intake is 40% lower than in the richest ones, while bread intake is 43% higher. In conclusion, if a food fortification program were to be based only on milk as a vehicle, it would not reach the poorest families as effectively as the richest ones and conversely, if it is based only on the fortification of bread, the opposite situation will occur.

These two alternatives of complementation, related biologically and socioeconomically, are the foundation for proposing a fortification program based on the use of two vehicles: whole-milk plus wheat flour.

If a food fortification program were to be based only on milk as a vehicle, it would not reach the poorest families as effectively as the richest ones and conversely, if it is based only on the fortification of bread, the opposite situation will occur.

Barriers to Iron Fortification of Milk

While there is extensive experience in the use and effectiveness of wheat fortification, the addition of iron to fluid milk has some difficulties related both to the bioavailability of the compounds and to the organoleptic changes induced by them.

Ferrous sulfate is known to have a high bioavailability. However, it catalyzes fat oxidation and causes unacceptable flavor and color changes in several foods, including fluid milk. When ferrous sulfate is used as a fortifier in milk, the addition of coffee, tea, or an extensively used infusion in Argentina called mate, produces a grey or blue discoloration of milk. Another problem related to the addition of ferrous sulfate is the hostile milieu in milk produced by the high concentration of calcium and low concentration of ascorbic acid, which limits the availability of iron in the intestinal lumen.

After CESNI's publication of the anemia prevalence in CBA and Misiones, a proposal of fortification of dried cow's milk used in food assistance programs with ferrous sulfate (15 mg of elemental iron per liter of reconstituted milk) plus ascorbate (50 mg/liter) was submitted to the National Congress. This initiative failed, however, because families soon after breast-feeding have the strongly established habit of introducing fluid milk and not dry milk. As a result, the use of infant formulas in Argentina is very low and strictly limited to the first months of life.

As a consequence of the motivation of the local dairy industry, in the last few years two new compounds have been developed and studied in animals and humans. One of them is based on ferrous sulfate microencapsu-

lated within a lecithin liposome and the other is an iron chelate (ferric glycinate).

Both compounds were developed by local researchers, the chelate by Valencia et. al., funded by the National Research Council (Conicet) and then purchased by Sancor Coop., and the microencapsulated form by Weill et. al. at the Research and Development Department of Mastellone Hnos. Mastellone Hnos. and Sancor Coop., the two most important members of Argentina's dairy industry, process more than 90% of Argentina's fluid milk. They were highly motivated to find a fortification agent of high availability to be used for fluid milk but devoid of the undesirable changes produced by the more reactive iron compounds.

The Ferric Glycinate Compound

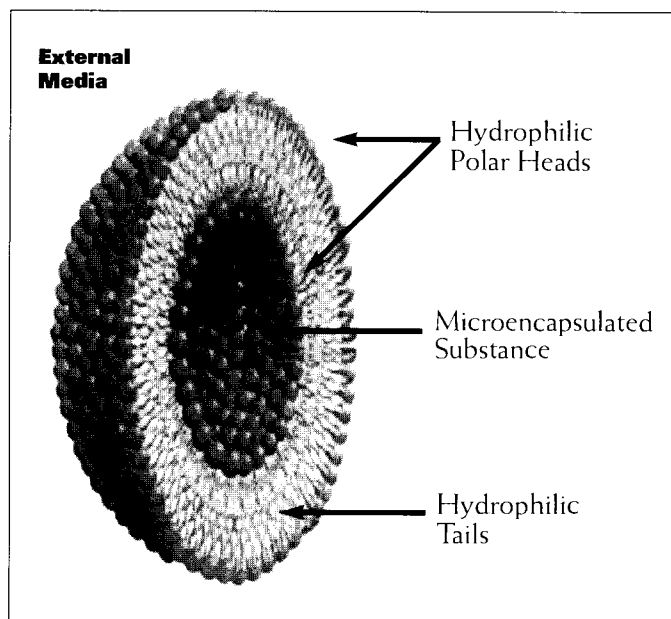
This compound is an iron amino-acid chelate composed of three molecules of glycine bound to one ferritation resulting in a heterocyclic ring compound (Patent N 249.049/96 University of Buenos Aires/SANCOR, Argentina). It has been proposed that this configuration could protect the iron from dietary inhibitors and intestinal interactions and also reduce the nutritional degradation of the milk during storage.

In vitro studies showed low pro-oxidant properties of the compound in model systems and in fluid milk, and experimental trials have demonstrated that the ferric glycinate has adequate bioavailability in both anemic and iron sufficient weanling rats.

It has been proposed that amino acid chelates could be absorbed like a peptide in the jejunum rather than as non-heme iron in the duodenum, and this alternative mechanism raises some concern about the role of iron stores in the regulation of iron absorption from the amino-chelate. If this proposed mechanism were true, there could be some risk of iron overload in the population when this compound is used in fortification programs.

In order to confirm the safety of this compound and to elucidate the role of iron stores in the regulation of its absorption, in a collaborative study with INTA's group (Chile) we studied the iron availability of two different doses of ferric glycinate using an isotopic model on adult volunteers. Thirty healthy male adults (two groups of 15 each) received 15 mg or 6 mg of elemental iron as ferric glycinate in 250 ml of liquid milk labelled with Fe 55, and its incorporation was compared with 60 mg of elemental iron as ferrous ascorbate (Fe 59).

A View of Microencapsulation



Liposome (Longitudinal View)

The iron bioavailability of the reference dose was similar in both groups, and iron absorption of ferric glycinate in the concentration of 6 mg/l was slightly higher (5.4%), but not statistically different (4%) than the iron absorption of ferric glycinate in a concentration of 15 mg/l of elemental iron. When iron absorption was standardized to 40% of absorption of the reference dose, the corresponding percentages of ferric glycinate absorption were 13.1% and 9.6% respectively. A direct correlation between the absorption of ferrous ascorbate and ferric glycinate ($r=0.75$, $p 0.001$) and a negative correlation with serum ferritin ($r=0.55$, $p 0.02$) could be seen in all the groups ($n=30$). These results are comparable with the iron absorption observed in other studies performed by the INTA's group using ferrous bis-glycinate in a concentration of 15 mg/l of elemental iron. In that trial the iron availability expressed as 40% of the absorption of the reference dose was 15% compared with 13.1 and 9.6 in our experience.

In conclusion, these results related to the regulation and bioavailability of this new compound show that well-nourished subjects present a reduced iron absorption of ferric glycinate, and there is an inverse correlation between iron stores and ferric glycinate absorption, confirming that iron glycinate chelates absorption is regulated by body iron stores and dispels the risk of iron overload in its use as a milk fortificant.

A second study recently performed at INTA compared, using a similar experimental design, the iron absorption using ferric glycinate in the fluid milk produced by the dairy industry's SANCOR. One liter of pasteurized fluid milk has 8 mg/l of elemental iron as ferric glycinate, a concentration at which there are no problems in stability and taste of the final product. The main difference in the industrialized milk other than the lower concentration of the fortification is the higher concentration of ascorbic acid than in the experimental formula prepared for the previous studies. The iron absorption of this fortified milk (ascorbic acid 12 mg/l and ferric glycinate 8 mg/l) was 12.9% expressed as 40% of the reference dose. This excellent absorption confirms the enhancing role of the ascorbic acid shown in many other studies. It has been demonstrated that when the molar ratio reaches 2:1 (AA to iron) the iron absorption increases by 36%. In this study the molar ratio was 1:4 and the increase in absorption was nearly 100%, allowing a reduction in the fortification concentration from 15 mg/l in the earlier study to 8 mg/l of elemental iron as is presently commercialized in Argentina.

The Ferrous Sulfate Microencapsulated Compound

Mastellone Hnos. developed a liposome containing a solution of ascorbate and ferrous sulfate that was stable at room temperature and over the entire shelf-life, was resistant to milk industrialization processes and that did not produce changes in taste or color of the product.

In order to evaluate the availability of the compound, two groups of 30 mice were fed with ferrous ascorbate and ferrous sulfate in water. The iron absorption, evaluated by the method of radio-labelled iron in these two groups, was used as a reference standard and presented an average of 4.9% and 4.3% respectively. To evaluate the interaction of milk components on the ferrous sulfate absorption, two other groups of animals were fed, one with ferrous sulfate in milk and the other with the iron micro-encapsulated. Both compounds showed a lower absorption than the reference dose in water, but the interaction with milk was significant in the former (3.2%) and practically negligible in the iron micro-encapsulated compound (4.5%). This experimental data confirmed the better absorption of the micro-encapsulated form in fluid milk as a consequence of the protection of the phospholipid bilayer on the interaction between iron and factors in the milk.

A horizontal bar chart comparing the percentage of ferrous sulfate (stippled bars) and microencapsulated compound (solid black bars) absorbed in seven different foods. The x-axis is labeled '% absorbed' and ranges from 0 to 20 in increments of 5. The y-axis lists the foods: Milk, Yogurt, Cereal, Chocolate, Tea, Coffee, and The Mate. For each food, the ferrous sulfate bar is on the left and the microencapsulated compound bar is on the right, starting from the same point.

Food	Ferrous Sulfate (%)	Microencapsulated Compound (%)
Milk	5	11
Yogurt	4	6
Cereal	3	8
Chocolate	6	19
Tea	4	4
Coffee	4	6
The Mate	5	11

These experimental results confirmed that micro-encapsulated iron added to fluid milk provides a non-hemic iron of good bioavailability, resistant to the usual manufacturing processes of dairy products without suffering alterations, either in the bioavailability of the iron or in the sensorial properties of the fortified milk.

In practically all cases, the absorption of iron from the microencapsulate was similar to or higher than that of the ferrous sulfate used as a reference.

As was done with the other compound, the iron bioavailability in humans was evaluated in collaboration with INTA in a group of adult male volunteers using the incorporation of iron to hemoglobin with Fe 59 and Fe 55 as markers. In this study, 15 healthy male adults (average age 27 years) received 250 ml of whole milk fortified with 15 mg of elemental iron per liter (Fe 55) as the micro-encapsulated form described earlier. The next day the group received the reference dose as ferrous ascorbate with Fe 59.

The absorption of iron from the micro-encapsulated ferrous sulfate in a concentration of 15 mg/l of elemental iron was 1.9%. This low net absorption was due to the fact that all the individuals were male in an excellent iron nutritional status. When iron absorption was standardized to 40% of absorption of the reference dose, the corresponding percentage of iron absorption was 9.2%.

As was mentioned in the case of the ferric glycinate, the micro-encapsulated iron absorption could be

Una de cada tres personas en el mundo, puede tener anemia.

La Organización Mundial de la Salud.

**LA SERENISIMA
TIENE UNA BUENA NOTICIA:
LECHE ULTRA CON
SULFATO FERROSO (HIERRO)**

Según la Organización Mundial de la Salud, una de cada tres personas en el mundo sufre deficiencias de hierro y puede tener anemia, sus síntomas. Si en su familia hay quienes no se alimentan adecuadamente por el ritmo y las exigencias de la vida cotidiana, es difícil y necesario consultar con su médico, puede ser que tengan un cierto grado de anemia. Muévete rápido: una medida saludable y acertada es tomar diariamente Leche La Serenisima Ultra Fortificada con Hierro, la única que posee Sulfato Ferroso (Fe), el más seguro y el de más sencilla asimilación.

* La Leche La Serenisima
no es un sustituto de la alimentación
de los niños de una lactancia materna.



48 Dairy Products

improved with the addition of ascorbate to the milk. This assay is presently being performed using the double tracer iron method.

In summary, both compounds, ferric glycinate and micro-encapsulated ferrous sulfate, are safe and have almost the same good bioavailability along with the advantages that are useful for fluid milk fortification. They do not cause changes in the organoleptic properties of the milk as do the more reactive compounds previously used for milk fortification.

History of Iron Fortification in Argentina

The history of iron fortification in Argentina is a long process started by a non-governmental initiative in performing the population surveys mentioned and by the development of these new compounds. The next step was the marketing by the dairy industry of two fortified milks targeted to prevent iron deficiency. The non-governmental sector again assumed the responsibility of promoting the importance of an iron deficiency campaign to increase public concern at least minimally and to help the public make sound choices regarding fortified foodstuffs. Extensive use of the media and lay press, advertisements, scientific workshops and publications were the tools used to sensitize pediatricians and mothers to the high risk. Despite this, the sales of fortified milk actually represent a figure slightly lower than 10% of total fluid. Why is this happening?

Consumer beliefs about iron fortification were studied in motivational panels of different socioeconomic levels and age groups. In a broad sense, and considering the limitations of this kind of methodology, people do not believe in the preventive value of the iron in milk because they mistrust the true presence as well as the efficacy of the iron compound in the milk. Most of those inter-

viewed, especially the group of mothers of infants, remarked on the lack of government support or the negative counseling of their pediatrician.

It is important from a customer point of view that the food fortification program have the endorsement of the government (Minister of Health or Secretary of Agriculture), the collaboration of the professional associations, and of course the support of the industry.

A future step for fortification is the proposal of a new law on iron fortification, but this time with an important public awareness campaign about the importance and consequences of iron deficiency.

Argentine Flour Legislation Proposal

A proposal of new legislation presently being discussed in the Argentine Congress includes the following statements:

- All wheat flour must be fortified with iron, niacin, vitamin B₁ and B₂ and folic acid.
- All food assistance programs must use fortified foods.
- All whole-milk, milk derivatives and infant foods must show a label saying "this foodstuff fulfills the requirements of the anemia law," according to the amount and iron bioavailability specified in the law.
- Specifications for a food educational campaign.

Evaluation of a Fortified School Breakfast Program in the Andes of Peru

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Abstract *A fortified school breakfast providing 60% RDA for most vitamins and minerals and 100% for iron was distributed daily to half a million children. While the cost was \$.22 per breakfast, the cost of the multiple micronutrient component was less than \$.005. After six months the prevalence of anemia decreased from 66.3% to 14.1% among the children in the program. Educational assessments indicate improved rates of attendance and school performance. Based on these results, the government of Peru now fortifies food assistance programs that reach nearly 2.5 million children.*

Introduction

In Peru there is an extended history of state-sponsored School Breakfast Programs (SBP). And as you may confirm from your own experience, the phrase "they are here to stay" is an indisputable truism. It is unfortunate that for more than three decades the lack of rigorous evaluations on the effectiveness of such programs has prevented us from learning more about their effects and potential.

This presentation concerns how the idea of food fortification was wedded to the governmental idea of launching a new SBP. It also covers the role of the Instituto de Investigación Nutricional (IIN-Nutrition Research Institute) in designing, implementing and evaluating the program's impact.

In 1993 the Government of Peru, through FONCODES, the agency that oversees most of the social spending in the country, established a school breakfast program aimed at improving the diet of participants in five economically impoverished sectors of the Andes. This mandate was implemented jointly with the Nutrition Research Institute, which provided technical advice and managerial expertise.

Rural areas in the Andes, where the program was implemented, are characterized by a subsistence economy, lack of basic services, a monotonous diet and poor health indicators. It is no surprise that here we find the

highest rates of micronutrient deficits in the country. For instance, the prevalence of stunted growth reaches one in every two children under five years of age. According to a recent survey, among those between 6-71 months the prevalence of iron-deficient anemia is about 25%, while vitamin A deficiency ($<20 \mu\text{g/dL}$) is in the range of 30 to 40%.

The Breakfast Design

The planning team concluded that these Andean children needed a high quality diet. They opted for breakfast as the choice of meal for two reasons. First, it would help to provide an extra source of energy to children who routinely walk long distances from home to school and have a poor breakfast or none at all. Second, because breakfast was a good vehicle for fortification with several nutrients and micronutrients.

The nutritional composition of the breakfast was defined according to information obtained from previous studies on local dietary intake. For school children between five and ten years old the breakfast provided 30% of their daily energy requirements, 60% of their recommended dietary allowances (RDA) for most minerals and vitamins and 100% of their daily iron requirement.

An additional feature of the breakfast is that it was a ready-to-eat meal consisting of a cake and an instant milk-like beverage. This prevented time-consuming

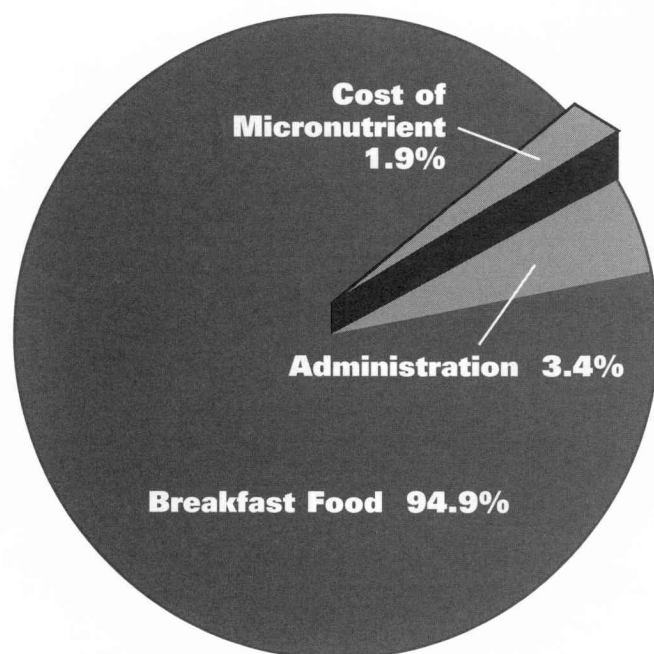
A significant improvement in school attendance rates was observed in the experimental group, while desertion rates doubled in the control group.

preparation activities and also assured a fixed amount of nutrients in the children's diet. Before being produced and distributed, the breakfast was tested among potential recipients for palatability and ease of preparation. Finally, through a public bid, six private industries were selected to produce and distribute the breakfast in the selected Andean regions.

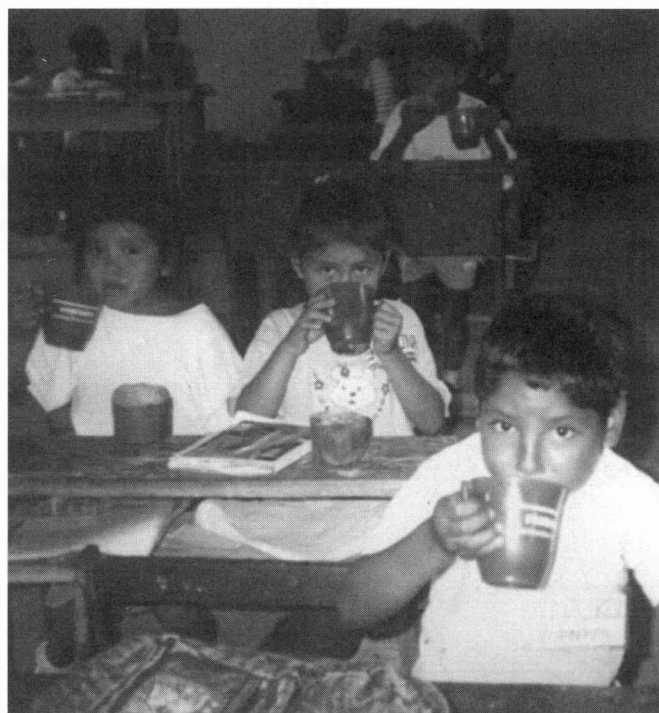
Participation of Grass-Roots Organizations

The IIN, responsible for the School Breakfast Program implementation, decided to run the program through local committees organized by the children's parents and teachers. Each of these so-called Núcleos Ejecutores was formed of several neighboring communities and had the

Program Cost Structure



Significant impact was achieved for an incremental cost of only 1.9%.



Breakfast was the meal of choice because it gave a good start to the day for children who walked to school, and because it was easy to fortify with several nutrients and micronutrients.

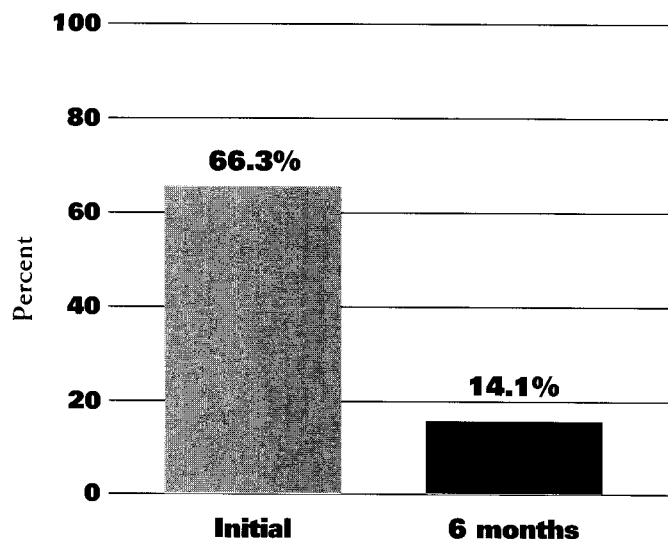
responsibility of distributing and preparing the breakfast at the local school. The local committees also were given a key control mechanism: they issued a voucher to the food producer at the point of delivery every month, which was later cashed at a local private bank. In doing so the program not only kept a tight control on the private producer, but also alleviated the need for a huge and costly bureaucracy.

By 1996 the program had reached six poor Andean regions and distributed the breakfast to more than 500,000 school children every day at a total cost per ration of US\$ 0.22, including the distribution and supervisory activities. A breakdown of the program's cost structure shows that adding the micronutrient amounted to scarcely 1.9% of total costs, while the breakfast itself represented 94.9%, and the operational costs 3.2%.

The Evaluations

Unlike similar cases, the need to answer key questions on the program's impact was present in the minds of its managers from the outset. This was instrumental in meeting the two minimum criteria for a sound evaluation, i.e., the existence of a control group and a baseline assessment of relevant program endpoints.

Percentage of children with anemia at the beginning of the program and 6 months later



Studies showed a dramatic drop in IDA following the school breakfast program intervention in Peru.

Two evaluations were conducted during the first year of the program's implementation. In the Central Andean town of Matahuasi at 3,000 meters altitude an institute team assessed the program's dietary and nutritional impact during 1993. Later that year, in September through December, a group of researchers assembled by the University of California at Davis (UCD) conducted another investigation in the province of Huaraz, at 3,300 meters of altitude and 400 kilometers north of Lima. Here we sought to ascertain the short-term impact of the program on psycho-educational performance, school attendance and diet. The first of these three objectives was particularly important, since the cognitive risks of skipping breakfast have repeatedly been demonstrated under laboratory conditions.

Since participating schools were enrolled in the program in a phase-in fashion during the school year, the researchers in both teams were able to randomly assign them to either receiving the program's breakfast immediately or to delaying it for a few months (the control group).

Results

Both evaluations document a significant dietary improvement among those receiving the program's breakfast. This was true not only for energy and protein but also for several micronutrients, including zinc, iron, vitamin

A, and iodine. Moreover, neither of the studies found that the improvements in children's diets was accompanied by food substitution into homes.

The case of iron in particular is worth mentioning. Iron intake, which was well below children's daily requirements at baseline, jumped above their RDA at both evaluation periods, two and seven months after the program's initiation. In agreement with that finding, a before-after evaluation conducted solely in the intervention group in Matahuasi found that the prevalence of anemia fell from 66% to 14%. Despite the limitations of this one group design, the finding is encouraging and agrees with the dietary evidence. Thus, reversing Iron Deficiency Anemia under programmatic conditions is an important achievement that certainly calls for more rigorous evaluation for confirmation.

A significant improvement in school attendance rates was also observed in the short-term evaluation in Huaraz. In Matahuasi, on the other hand, we found that by the end of the school year desertion rates had doubled in the control group. Interestingly, the UCD team's observations also found that in the short term, among those receiving the breakfast, children who were relatively heavier did better in a vocabulary test.

Conclusions

This program is now in its fourth year of uninterrupted operation, and thanks in part to these results, governmental authorities have been persuaded to continue funding it. In addition, government authorities have started to supplement other food aid programs with a similar micronutrient content. These programs now reach nearly 2.5 million children six months to three years of age.

School breakfast programs may prove to be a good food fortification strategy, since they not only enjoy political allure and sympathy from the public, but also have the institutional support of the school system. These factors, together with a persuasive input from the scientific community, can make the difference in the nutrition of children, particularly in isolated rural areas that are hard to reach through the market or other conventional means.

We are working now to provide figures of the program's cost-effectiveness and cost-benefit, a much-needed approach in this world, where social spending, in addition to the moral imperative, needs a strong economic justification.

Milk Enhancers and Powdered Beverages

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Abstract *About half the milk consumers in Mexico drink milk only after adding modifiers. Chocolate powder, one of the most popular modifiers, is consumed primarily by children and mothers, making this an attractive vehicle for delivery of micronutrients. After determining primary micronutrient deficiencies in conjunction with the nutrition experts in Mexico, the manufacturer upgraded the powder with 40% RDA of iron, 15% RDA of vitamin A and 20% RDA of iodine. Collaboration with the University of Chile demonstrated excellent bioavailability in human subjects. The product was demonstrated to have excellent acceptability and stability during shelf-life. The fortified product was launched with a seal of acceptance from the Mexican Pediatric Association.*

Background

More than two billion people worldwide suffer from iron, vitamin A and iodine deficiencies. If not prevented and/or corrected, such deficiencies have been repeatedly demonstrated to cause stunted growth, impaired mental development, poor school performance, increased morbidity and mortality rates, reduced work output and low self-esteem. In all, micronutrient deficiency is a serious public health and economic development problem. That is why the phrase "Hidden Hunger" was coined to describe the true nature of micronutrient deficiency. It is also the reason that combatting micronutrient deficiencies (particularly in vitamin A, iron and iodine) is emerging as a top priority for global health and economy.

Criteria for Micronutrient Fortification

Micronutrient fortification of foods and beverages is one of the preferred approaches of preventing micronutrient deficiency. We would like to use our micronutrient fortification program of a chocolate-based powder as a model for fortifying foods and beverages with multiple micronutrients. The objective is to deliver a highly bioavailable/stable iron, vitamin A and iodine via a chocolate powder without changing the color and flavor of the finally consumed product. The success of any fortification program is dependent on two key factors, namely the vehicle and the fortificants. These may interact to cause the development of undesirable properties

such as poor bioavailability, accelerated vitamin degradation and undesirable color and flavor.

Identifying a Suitable Vehicle

The vehicle should be centrally processed, have an excellent taste and appearance, not interfere with the bioavailability of the added nutrient and reach the target population. Are milk modifiers, such as chocolate powders, a suitable vehicle for micronutrient fortification? To gain insight, we studied the habits and practices of those consuming milk modifiers in Mexico. We found that about 50% of Mexicans consume milk with milk modifiers. Surprisingly, only about 16% consume pure milk all the time. The remaining group, about 34%, consume their milk with either milk modifiers or alone. Furthermore, the major consumers are children, mothers and adolescents. Thus, milk modifiers have a potential to be a suitable delivery system for micronutrients.

Compatibility of Fortificants

The vitamins and minerals added to foods and beverages should not affect the taste and appearance of the vehicle. Fortification with iron in particular is complex and difficult. When highly bioavailable iron sources, e.g. ferrous sulfate, are used, they react with several food components. The results include development of undesirable color and flavor, degradation of vitamins and development of a metallic aftertaste.

Bioavailability of Fortificants

For fortification to have an impact on the nutritional status of the population, the added nutrient should not only be compatible with the vehicle but also bioavailable. When we talk about bioavailability, we are referring to the fraction of the ingested nutrient that is absorbed and becomes available for the various biological functions. The amount of a nutrient in a product only indicates the quantity, while bioavailability shows the efficacy/quality of the nutrient. For instance, even though most of the foods we eat daily contain substantial quantities of iron, the percent of iron absorbed is quite variable. The absorption of iron from commonly consumed foods ranges from 1% to 20%. In general, the iron from foods of plant origin, such as rice and beans, is poorly absorbed. In contrast, the iron from foods of animal origin, such as meat, is highly bioavailable. Indeed, iron deficiency anemia exists in both industrialized and developing countries. However, since the staple diet in developing countries is mainly of plant origin, meaning the quality of the dietary iron is poor, there is more prevalence of iron deficiency anemia.





Challenge of Multiple Fortificants

The fortificants for both vitamin A and iodine are already identified. Both retinol palmitate and beta carotene are commonly used as vitamin A sources. Potassium iodide and potassium iodate are also used as

iodine sources. With both nutrients, the problem is primarily poor stability. Even though a technology is needed to stabilize these nutrients, the problem is currently addressed either by using proper packaging or via overaging.

With iron, however, the problem is more complex, and both compatibility and bioavailability are important issues. Currently, there are a number of iron compounds that are allowed for food fortification. In 1975, Fritz and Pla, from the United States Food and Drug Administration, compared the bioavailability of iron from a number of iron sources. Ferrous sulfate, a source of highly bioavailable iron, was used as a standard, and all the other iron compounds were compared to it. On the basis of bioavailability values, there are two groups of iron compounds. The first group includes compounds that are sources of highly bioavailable iron. The second group contains compounds that have poorly bioavailable iron. The iron compounds that are highly bioavailable, such as ferrous sulfate, ferrous gluconate and ferrous fumarate, are not compatible with the foods and beverages that are commonly used as a vehicle. The iron sources that are compatible, such as ferric pyrophosphate and reduced iron, have poor bioavailability. The challenge for the food scientists and food industries is to use these highly bioavailable iron compounds without affecting the organoleptic properties of the product and the stability of the vitamins.

Iron Sources Currently Used in Food Fortification

Iron Source¹	Relative Cost Index	Relative Bioavailability	Solubility	Compatibility² With Foods
Ferrous Sulfate (hydrated) (20%)	1.0	100		Poor
Ferrous Ammonium Sulfate (14%)	2.1	99		
Ferrous Gluconate (12%)	5.1	97		
Ferrous Ammonium Citrate (10%)	5.0	107		
Ferrous Fumarate (33%)	1.3	95		
Ferric Citrate (17%)	4.8	73		
Ferric Pyrophosphate (25%)	2.3	45		
Ferric Orthophosphate (28%)	4.1	3-46		
Reduced Iron (97%)	0.5-1.0	8-76		
Sodium Iron Pyrophosphate (15%)	3.5	14	Poor	Excellent

1. Values in parenthesis show approximate iron content.

2. Excellent compatibility, the iron compound does not interact with the food components.

Thus, the objective of our chocolate powder fortification is to deliver highly bioavailable iron and stable vitamin A and iodine without affecting the flavor and color of the consumed product. We have succeeded in fortifying a chocolate-flavored milk enhanced with 7.2 mg iron per 25 g serving (40% USRDA). We used ferrous fumarate as a source of highly bioavailable iron. As a vitamin and as an enhancer of iron absorption, vitamin C was included at 75% of the USRDA (45 mg) per serving. We added vitamin A as retinol palmitate and iodine as potassium iodide at 15% USRDA (750 IU) and 20% USRDA (30 g) per serving, respectively.

Product Evaluation

The challenge with multiple micronutrient fortification is to demonstrate that the claimed nutrients are there during the shelf-life of the product, that they do not affect the organoleptic property of the vehicle, and that they are bioavailable. Our data from the habits and practices study in Mexico demonstrated that chocolate powders are purchased to improve the taste of milk and provide nutrients that complement the staple diet. Does fortification with bioavailable iron, vitamin A and iodine have an effect on the color and flavor of the chocolate milk beverages? What is the bioavailability of the iron? How stable are the iodine, vitamin A and vitamin C?

Product Acceptance

Will the fortification of chocolate powder with bioavailable iron, vitamin A and iodine affect the color and taste of the final product? The approach of using ferrous fumarate as an iron source for chocolate milk-based beverages is not without a technical challenge. According to Hurrell et. al., ferrous fumarate containing chocolate powders that are prepared with either hot water or milk cause an undesirable color change from the standard brown to an unacceptable gray color. We evaluated the product, which is fortified with ferrous fumarate for overall acceptance, color and flavor. Results were obtained from four weeks of a home-use test. Comparison was made between chocolate powders with either ferrous fumarate or ferric pyrophosphate. The results showed that incorporation of ferrous fumarate into chocolate powder, as a source of highly bioavailable iron, has no effect on the flavor and color of the finally consumed chocolate milk beverage.

Iron Bioavailability

What is the bioavailability of iron from chocolate powder? For iron fortification to have an impact on the iron status of the population, the added iron has to be bioavailable. Dietary components play a key role in influencing iron absorption. Both meat and vitamin C are known enhancers of iron bioavailability, whereas components such as phytates, which are found in cereals such as corn, wheat and rice; tannins, which are found in legumes and tea; calcium and phosphates, which are found in dairy products and tortillas; and oxalates, which are found in vegetables such as spinach, are potent inhibitors of iron absorption. The work of Stekel et. al. is a typical example. By using a double isotope technique, they determined the absorption of iron from ferrous sulfate when delivered via either cow’s milk or water

Iron Bioavailability from Chocolate Powder

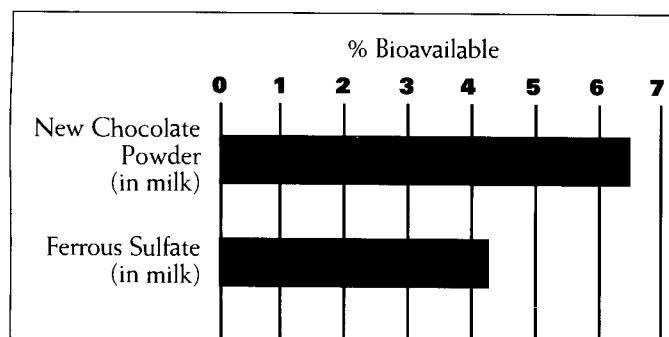
(Hemoglobin Depletion/Repletion Assay in Rats)

Treatments	Iron Source	Hemoglobin Gain (g/dl)
Chocolate Powder	Ferrous Fumarate	4.12
Chocolate Powder	Ferric Pyrophosphate	1.61
Control	Ferrous Sulfate	4.03

in humans. The absorption of iron from ferrous sulfate added to either milk or water was about 4% and 35%, respectively. Indeed, the results showed that milk is a potent inhibitor of iron absorption.

We did evaluate the bioavailability of iron from our chocolate powder by using a hemoglobin depletion-repletion technique in rats. The procedure was straightforward. The animals were made anemic by feeding them an iron-deficient diet. During the repletion period, the anemic rats were fed diets that contain different iron sources. At the end of the study, the gain in hemoglobin was measured. Ferrous sulfate was used as a positive control and ferric pyrophosphate was used as a negative control. The two-weeks hemoglobin gain values(g/dl) were 4.1 from the ferrous fumarate-fortified chocolate

Iron Bioavailability Comparison



powder, 1.6 from the ferric pyrophosphate-fortified chocolate powder and 4.0 from the standard, ferrous sulfate. These results demonstrate that the iron from the chocolate powder fortified with ferrous fumarate is highly bioavailable. In fact, it is as good as that from ferrous sulfate, the standard. In contrast, when the iron source is ferric pyrophosphate, the hemoglobin gain is significantly decreased.

The data generated from the animal study showed that the iron from chocolate powder fortified with ferrous fumarate has excellent bioavailability. This observation was also confirmed by conducting a clinical study in collaboration with Dr. Tomas Walter at the University of Chile in Santiago. The iron from chocolate powder in milk was compared to that from ferrous sulfate in milk. The methodology used was the dual isotope technique. Women of childbearing age received test samples labeled with radioactive iron. The radioactivity retained in the blood after 14 days was utilized to calculate the iron bioavailability values. From the chocolate powder in milk, 6.7% of the iron was absorbed, while only 4.3% was absorbed from the control, ferrous sulfate, in milk.

Vitamin A Stability and Bioavailability

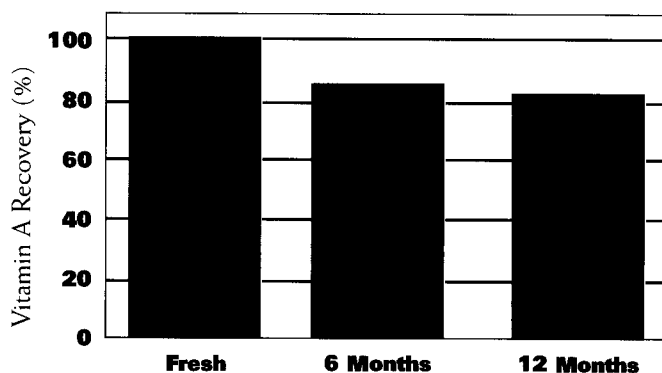
The challenge with vitamin A fortification is mainly due to poor stability during processing, storage and cooking. It is sensitive to oxygen. This oxygen-mediated degradation of vitamin A is accelerated by iron. We have evaluated the stability of vitamin A from a chocolate powder during an accelerated storage study. The samples were stored under accelerated conditions for 6 to 12 weeks, which is equivalent to 6 to 12 months. The results showed that vitamin A is stable in the presence of iron for up to one year. We have determined the bioavailability of vitamin A in rats by using the vita-

min A depletion-repletion assay. Comparison was made against a standard, retinol palmitate, in a semi-purified diet. The bioavailability, as indicated by the level of the retinol palmitate in the liver, demonstrated that the vitamin A from the chocolate powder has excellent bioavailability. In other words, the chocolate powder is an excellent vehicle for delivering vitamin A from retinol palmitate.

Iodine Stability

Like vitamin A, the problem with iodine fortification is stability. We have determined the stability of iodine. The results show that the iodine is still there during the shelf-life of the product. However, since reproducibility was found to be a serious problem, there is a need to develop an improved analytical methodology.

Vitamin A Stability in a New Chocolate Powder



Conclusion

The results indicate that multiple micronutrients can be delivered via a chocolate-flavored milk modifier. The product contains iron from ferrous fumarate, vitamin A as retinol palmitate, iodine as potassium iodide and vitamin C as ascorbic acid. This is accomplished without the development of undesirable flavor and off-color of the finally consumed chocolate milk beverage. Challenges still remain in developing a fortification technology that addresses the problems related to compatibility, bioavailability and stability. Finally, for the product to have impact in combatting micronutrient malnutrition, the acceptance of the finally consumed product, the stability of the nutrients and the product and the bioavailability/efficacy of the micronutrients (particularly iron) have to be evaluated.

Milled Grains & Cereal Products



Opportunities for Wheat Flour Fortification

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Abstract *Rice, corn, wheat and their derivatives like flours and meals are preferred vehicles for fortification because most staple foods consumed in the developing countries fall in this category. Routinely performed in most developed countries, technical advances have enabled flour fortification to be transferred to a number of developing countries. New micronutrient premix powders offer the nutritional value, cost and stability that ensure that fortified flour will look, feel, taste and smell like unfortified flour. Initiatives in rice fortification are overcoming barriers of incompatible consumer habits, cost, and diversity of small village-based processors.*

Introduction

Cereals are the fruit or seed of grasses. On a global basis they provide half of all calories consumed. In their raw form as wheat, rice, maize or as derivative products such as breads, pastas and biscuits, these cereals are the biggest contributor of protein to world diet.

China and Russia grow the most wheat but consume most of what they produce. Most countries import much of their wheat, usually from the major wheat exporting countries: Canada, US, Argentina, Australia and France. The importation of wheat is often under government control and involves large, multinational trading operations like ADM, Bunge, Cargill and Continental Grain. These global companies generally own and operate flour mills and have been involved in fortification of flour for decades. A few countries obtain some wheat as food aid but most imports are straight commercial transactions.

Wheat consumption is particularly high in the Middle East. In countries like Syria, Algeria, Turkey and Iran wheat consumption is about half the total caloric intake and ranges up to nearly 600 grams a day. In Egypt and Saudi Arabia, where wheat products provide a bit more

than a third of the caloric intake per capita, consumption is about 300 to 400 grams per day. While many countries in this region grow significant amounts of wheat, imports are still needed to meet consumption. Countries like Egypt and Syria import more than half their requirements. While overall consumption in Asia is lower, in many nations trends indicate a rise in consumption. For example, on a per capita basis, from 1992 to 1996 wheat consumption was up 44% in Indonesia and about 33% in Thailand.

Rice is the second most consumed cereal. There are many different varieties but three basic types of products: brown rice, white or polished rice, and rice flour. Rice is the dominant staple in Asia, making up half to three quarters of the caloric intake. However, in Latin American countries like Ecuador and Peru, rice constitutes about one-fifth of the total calories consumed.

Corn, or maize, is used heavily in Africa and Latin America. In African countries like Malawi, Zambia, Zimbabwe and Kenya, maize products make up 40-60% of the caloric intake. In many Latin American nations nixtamalized corn flour is used in tortillas and chips.

Wheat Consumption in Selected Countries

Country	Consumption Per Cap (g/day)	% of Caloric Intake
Syria	595.40	51.5%
Algeria	587.81	54.2%
Turkey	557.07	42.7%
Iran	473.42	45.6%
Bulgaria	423.64	37.9%
Italy	404.93	30.1%
Egypt	398.52	35.0%
Saudi Arabia	348.79	36.3%
Chile	325.42	33.4%
Argentina	316.03	26.6%
Sri Lanka	153.34	17.0%

Globally, cereals provide half of all calories consumed. Wheat consumption is particularly high in the Middle East.

Milling Cereals

All cereals are processed or milled before they are consumed. Milling of wheat and maize separates the inside, starchy endosperm from the bran covering and germ. The endosperm becomes flour. Between the endosperm and the bran, the aleurone layer contains high levels of micronutrients. Many are lost during the milling process. While caloric density actually is increased during the milling process and the protein content remains about the same, vitamins and minerals are lost.

The extraction rate is the flour yield or percent of flour that the miller "extracts" from the whole wheat. Wheat contains around 82% endosperm, which would be the theoretical maximum extraction rate. Because mills are not totally efficient, the actual extraction rate is less than that, usually in the 72 to 76% range. Some highly efficient mills with modern equipment can get up to 78% extraction.

The higher the extraction rate, the higher the ash content of the flour and the higher its micronutrient content. As the extraction rate decreases, the iron and

zinc content drops. In fact, the final content of iron and zinc in the flour is about a third of what was contained in the wheat. All other micronutrients, vitamins and minerals follow this same pattern. Phytic acid and fiber, which are detrimental to the absorption of some micronutrients like iron, are also lost in the milling process. Their levels are much lower in flour than in the original wheat.

While the Green Revolution has greatly increased cereal production, providing billions with crucial calories and protein, diets high in milled cereals have low micronutrient contents compared to past diets. This is a major factor in the current overall worldwide micronutrient shortage. The best way of dealing with this is enrichment or fortification. The terms "fortification" and "enrichment" are often used interchangeably. However, in my view there is a clear difference. Enrichment should refer to restoring nutrients lost in the milling process. I define fortification as adding micronutrients to a level sufficient to combat demonstrated population-wide micronutrient deficiencies.

Opportunities and Barriers

Bread and other flour products are attractive vehicles that can effectively carry micronutrients to deficient populations. Bread is consumed daily, in relatively constant amounts and often with meals. Moreover, it is included in the diets of all age groups, socioeconomic strata and is consumed by women and children.

From the point of view of achieving goals for the elimination of micronutrient malnutrition, there is a distinction between enrichment and fortification that we might call political. It is often easier to establish a flour enrichment program in many countries rather than starting off with a true fortification program. The argument of adding back what was lost on processing is easier for some people to accept than explaining how traditional foods like breads can become a public health intervention to end micronutrient malnutrition.

One of the major concerns expressed by millers regarding the addition of micronutrients is whether it will affect or change the flour and baked products made with the flour. Based on many years of test baking and field experience, we can say that the addition of iron, calcium and vitamins to flour and bread, when done properly, does not alter in any way the taste, color, appearance or general baking properties. Fortification of wheat flour is truly invisible to the consumer.



Since bread is consumed daily in many different countries, it provides an excellent vehicle for fortification with micronutrients.

Fortificants and Process Technology

Of all the nutrients added to flour, iron is the most needed, the cheapest and the most likely to cause problems. Iron standards vary greatly. For example, while restoration levels are in the 30 to 40 ppm range, the UK and Venezuela have standards below that. In contrast, levels recommended by the Institute of Nutrition for Central America and Panama (INCAP) are higher.

While there are many different types of iron available, there are only two that are used in wheat flour: ferrous sulfate and reduced or elemental iron. Ferrous sulfate is recommended because of its good bioavailability, whenever it can be used without problems. Depending on factors like humidity, this includes bakery flour made with an extraction rate below 82% and stored no longer than a month, as well as semolina for use in pasta production. All other types of flour can be fortified with reduced iron.

All flour mills are continuous operations, while bakeries are batch operations. This means that the micronutrients, in the form of a single premix, must be continuously metered into the flour stream as it moves through the mill. The premix needs to contain the correct levels of nutrients, to be uniform and free-flowing. There are many premix companies with excellent quality products throughout the world. That makes the premix readily available and the cost quite competitive. Calcium is the one nutrient usually added separately, either as calcium sulfate, calcium triphosphate or calcium carbonate, owing to the large bulk involved.

The premix is added to flour at the mill through a machine called a feeder or dosifier. Such machines have existed for half a century. The older ones use a revolving disk or drum to deliver a constant rate of premix. The new ones use a screw run by an adjustable speed motor. The controls for the feeder can then be located anywhere in the mill, while the older units can only be adjusted at the feeder using a slide bar or similar device for constricting volume at the aperture. While the older units work perfectly well, newer equipment is available that will record continuous loss of weight in a feeder and tie that in electronically to some device measuring the rate of flow of flour for continuous, on-line adjustment.

The cost of a basic dosifier is \$2,000 to \$4,000 US dollars FOB United States. Because we do not want even this small capital cost to be a constraint to mills wishing to fortify flour, some premix manufacturers may assist in providing feeders to qualifying flour mills. Additional assistance in the design, engineering and installation of the dosifier and related equipment may also be available through the Micronutrient Initiative or other groups promoting micronutrient fortification of food staples.

Most flour mills in the Americas and parts of Europe are accustomed to adding micro ingredients to flour. Ingredients added to flour include enzymes such as malted barley flour or fungal alpha-amylase; bleaching agents, such as benzoyl peroxide; and oxidative dough improvers, such as ascorbic acid, potassium bromate and azodicarbonamide. Most of the mills that are found throughout Central America, the Middle East and the Far East are set up for adding micro ingredients, including vitamins and iron, even if they are not currently fortifying flour.

There are two basic methods for delivering the premix from the dosifier to the flour. One is to gravity feed the premix directly into a flour conveyor. The conveyor may be for the collection and blending of different flour streams, or it may be specifically for adding micro ingredients. If these conveyors are inaccessible, or if there is no space for additional dosifiers, the alternative, pneumatic system may be used.

The pneumatic system involves blowing the premix from the dosifier to a pipe or conveyor carrying flour. This involves installation of an air blower, a venturi tube assembly and piping. It is desirable that some flour mixing be provided past the point at which the premix enters the flour. Pneumatic systems have higher capital and upkeep costs than gravimetric systems.

Regulations and Standards

An enrichment standard means the level required in the final product. The level typically added is generally lower; the natural content of the nutrient in flour is being relied on to bring the total up to the standard. Keep in mind that the only benefit comes from the amount added and not the standard itself. Current flour enrichment standards in the United States and Canada include five required nutrients. Folic acid was added just this year to help reduce the incidence of neural tube birth defects. Calcium is optional in the United States, and Canada has additional optional nutrients which are seldom added.

Different countries may have different standards. For example, the compulsory iron levels required in Guatemala and Ecuador are nearly twice that of El Salvador, Panama or Nigeria. The INCAP standards, now being used in El Salvador, Guatemala and Nicaragua, require higher iron levels and will hopefully be adopted throughout Central America.

Having enrichment standards does not mean that enrichment is required. Standards only state what types and levels of nutrients can be added. Enrichment is required in a number of countries, but it is not required in the United States. Separate regulations are often used to make it mandatory. Some 33 states in the U.S., for example, have laws requiring that only enriched cereal products can be sold. Russia may also choose to require enrichment on a regional or even city level rather than for the whole country.

Quality Assurance

Flour mills and regulatory agencies use a variety of methods for insuring and ascertaining whether flour is being properly fortified. One of the most critical aspects of this is to properly adjust the dosifier to deliver the proper level of premix based on the flow of flour. This assumes that the flour flow is both constant and known, which is not always the case. Attempts to fortify flour in the Kyrgyz Republic were stymied by the flour mills not having a constant flow of flour. The millers had to install a conveyor that moved flour from one packout bin to the other in order to be able to uniformly enrich the flour.

The analytical tests are usually based on iron, but tests for vitamins are also available. Flour mills use a simple spot test to assess whether the flour has been enriched and to make sure it is not grossly under or over treated. Mills may then do occasional quantitative tests, as may government agencies regulating the program.

Costs and Benefits

The cost of cereal fortification is very low, but the contribution it makes to the diet and the resultant health benefits are very large. The cost of flour fortification increases the price of a 50 kg bag that normally costs anywhere from \$10 to \$20 by only a few cents. This shows up in the price the baker pays for the flour. In Venezuela, this is 10 cents per person per year, for example. This cost is a fraction of the normal fluctuation in the price of flour caused by normal variations in the price of wheat.

Bakers and millers may quite naturally object to the burden placed on their industry and this increase in the price of flour. Consequently, during the initial stages, governments may identify ways and means to intervene in order to distribute the price increase over several years. This makes the small increase truly invisible. However, it is not a good idea for the government to totally absorb the cost because once the government stops the subsidies, the fortification will stop. Cereal fortification must be sustainable, which can only occur if the consumer absorbs the cost.

While a bag of flour may show a small increase, a loaf of bread will not, since the increase is too small to show up in the local monetary units. For example, if a mill charged ten cents more for a 50 kg bag of fortified flour, a 500-gram loaf of bread made from that flour would contain 350 grams of fortified flour, costing the baker 0.007 cents per loaf. There is no way the baker can justify charging another penny for that loaf, although some will try. The baker will object to the price increase since he cannot easily pass it on, but eventually it will be lost in the cost of doing business.

Conclusion

In conclusion, fortification of wheat flour, bread and milled maize is a proven, cost-effective way to deliver more iron and other micronutrients to the people who need them. Many countries have been doing this for half a century. The technology is available and can be applied to many developing countries where the need for more micronutrients in the diet is great.

Enrichment of Precooked Corn Flour and Wheat Flour in Venezuela: A Successful Experience

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Abstract *Precooked corn flour is the most widely consumed food in Venezuela. However, it has a very low micronutrient content. Beginning with a 1992 Presidential Decree, public and private sectors have worked together to universally fortify this staple. After consensus was reached on a fortification profile for precooked corn flour, fortification was made mandatory. Each kilogram of precooked corn flour must include 2,700 RE of vitamin A and 50mg iron plus B complex vitamins. By 1994 surveys indicated that total iron consumption among poorer classes increased 25% and anemia prevalence in children was cut in half.*

Background

In 1983 Venezuela devalued its currency and economic crisis followed. The hardest hit were the poor, and there was a progressive reduction in the quality and quantity of food consumption available to the lower economic groups. This included lower consumption of meat, vegetables and fruits, cereals, grains and tubers. This in turn resulted in increased deficiency of micronutrients. Based on data from the Food Balance Sheets from 1990-1991, the average Venezuelan diet offered only the following RDAs: 72% for iron, 78% for vitamin A, and as low as 74% for vitamin B complex. Subsequent food consumption surveys confirmed this data for the lower socioeconomic strata, population segments C and D.

Although a variety of fortified food products, enriched voluntarily or by law, are available in the Venezuelan market, their prices are usually beyond the purchasing power of these C and D segments of the population. Consumed predominantly by the higher socioeconomic strata, these include powdered milk, breakfast cereals, cocoa beverages and some fruit juices. On the other hand, precooked corn flour (PCF) is consumed by virtually all segments of the population, particularly by those with lower purchasing power. In view of

this situation, in mid-1991 the National Institute of Nutrition started considering the feasibility of fortification of this popular food item.

The Food Vehicles

Precooked corn flour (PCF), made from the clean endosperm of the kernel, is a Venezuelan staple. It is used mainly for the preparation of *arepas*, a popular type of bread, and is the most widely consumed food in the country. According to Food Balance Sheets, in 1990 PCF accounted for 40% of calories derived from cereals and for 15% of the total caloric intake by the Venezuelan population. Subsequent surveys indicate that these consumption figures remained about the same throughout the decade and even increased slightly in 1996. For 1995 and the third semester of 1996 food consumption surveys carried out on a nationwide basis showed 76 and 79 g/person/day consumption of PCF respectively. It should be noted that this widespread staple has a very low nutrient content, offering 78% carbohydrates with less than 2 mg of iron per 100g and no vitamin A.

After PCF, wheat flour (WF) is the most widely consumed food in the nation. Venezuela imports around 25,000 metric tons of wheat. About 50% is used as bread

flour, 35% for pasta products, and 15% is used by the biscuit industry. Wheat flour consumption via bread products was 22/g/person/day in 1995 and 18 g/person/day in 1996. Moreover, in 1996 the Venezuelan Wheat Producers Association reported the output of national mills corresponding to 95.8 g/person/day for all flour except durum wheat flour, which is used in the manufacturing of pasta products. Therefore, along with PCF, wheat flour (WF) used in bread and bakery products seemed to be another excellent vehicle for fortification.

Initial Research and Development

The National Institute of Nutrition (NIN) started the research and development of fortification of PCF with iron (as ferrous fumarate), vitamin A, thiamin, riboflavin and niacin. First attempts were not satisfactory due to modifications caused by the fortificants in the organoleptic characteristics of the *arepa*. When tested by a panel of experts, the *arepas* made from fortified white corn flour presented an off color. Although differences in flavor and odor could not be detected, the ready-to-eat product was not accepted by the panel. As an alternative approach, fortification levels as well as the iron compound were lowered. Iron fortification at an average consumption of 80g/person/day would cover approximately 25% of the Venezuelan RDAs.

Presidential Decrees

With R & D completed by the NIN, in August 1992, by Presidential Decree, the Commission for the Nutritional Enrichment of Foods (CENA) was created with the specific task of coordinating and facilitating the enrichment of PCF. This decree also included a mandatory fortification profile. The announcement of this measure as an official policy, although fully supported by well-known Venezuelan scientific institutions and key Venezuelan nutrition leaders, provoked adverse reactions among the private sector. Key businesses had not been consulted in the formulation of the fortification profile, which specified both fortification levels as well as fortificant composition.

As a result of this industry reaction, a new mandatory fortification profile for the PCF was negotiated under the auspices of the CENA. The new profile was discussed and considered by government and industry within the framework of the local food habits and the preferences of the Venezuelan consumer of the well-known *arepa*. Thus, with the sustained support of the



Precooked corn flour (PCF) is a Venezuelan staple used mainly for the preparation of arepas, a popular type of bread, and is the most widely consumed food in the country, followed by wheat flour (WF).

CENA, and after several meetings and workshops, a fortification profile for PCF was agreed to by consensus between the official sector and private industry.

Reaching Consensus

With the participation of key representatives of the corn and wheat industries, the government and the media, CENA announced in February 1993 the official fortification decree for PCF. Following a specific request by the milling industry, the mills were given the option of achieving the iron fortification profile either as 30 mg of ferrous fumarate or as 20 mg of reduced iron. These figures were then included in the Official Venezuelan Bureau of Standards (COVENIN), mandatory Standard N 2135-96 "Precooked Corn Flour." As a result, since February 1993 all the PCF sold in Venezuela must be enriched.

The effect of fortification is clear. With the exception of riboflavin, an intake of 91.6 g of enriched PCF covered around 30% of the RDA for thiamin, niacin, vitamin A and iron. No vitamin A is provided by the PCF without fortification. Riboflavin had to be reduced from 0.4 to 0.25 mg/100 g due to the slight change of color of the *arepa* to a golden one.

Wheat Flour

In November 1992 the Venezuelan Wheat Producers Association (VWPA) presented a tentative and non-com-

pulsory fortification profile for wheat flour (WF). In March 1993 the CENA voted against the non-compulsory character of the fortification and shortly after, upon agreement with the VWPA, set in force the mandatory fortification profile of WF. These fortification figures were also included in the COVENIN, mandatory Standard N 217-94 "Wheat Flour." The standard source of iron would be ferrous fumarate, although lactate, gluconate, sacarate or another suitable source of iron could

be used as long as it guaranteed a level of iron absorption equivalent to that of ferrous fumarate. As expected, the fortified wheat flour, now in the market, provides more thiamin, riboflavin, niacin and iron than the plain wheat flour.

Quality Assurance

Quality assurance measures for monitoring purposes were implemented by several public agencies as well as by the individual millers. The National Institute of Hygiene is responsible for the quality assurance and compliance with the COVENIN standards of fortified PCF and WF. They manage the government's surveillance program. The National Institute of Nutrition maintains its own surveillance through a sampling program within the Metropolitan Area of Caracas, and also routinely receives PCF and WF samples from the interior of the country submitted by the regional agencies of the NIN. In addition, wheat flour samples are continuously taken in Caracas from bread factories and bakeries for routine verification of the fortification profile. Up-to-date results are encouraging. A majority of the values comply with the nutrification fortification profile of the COVENIN Standards for WF and PCF.

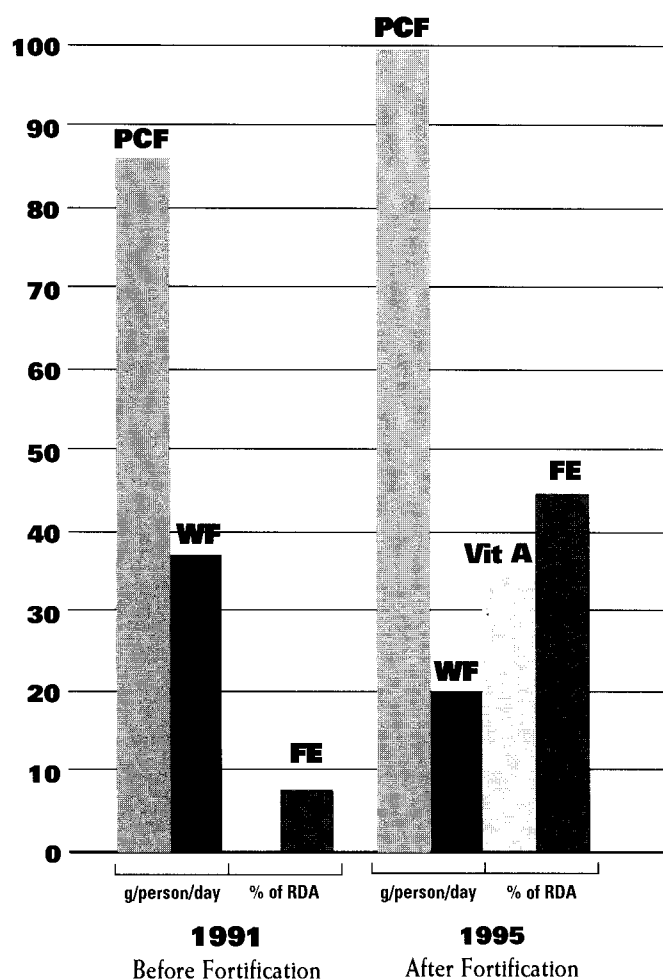
At plant level, industry maintains a constant surveillance and quality control of the ferrovitamin premix. For wheat flour, the premix is added at mill level and not at the bakery, thus assuring that the raw material PCF and WF contains the fortificants. For the pasta and biscuit industry, wheat flour is not fortified. This step is still voluntary.

Measuring Impact

A comparison of deficiency levels for the years before and after the fortification decree indicates a positive impact among lower socioeconomic strata populations for vitamin A, iron, B-complex, thiamin and riboflavin for the years 1990 to 1996. The difference in the intake of the five nutrients is striking. Prior to fortification, no vitamin A was provided by PCF and barely 9% was provided for thiamin, riboflavin, niacin and iron. After 1993 the percentages of the RDAs covered by the actual per capita consumption of fortified PCF among lower economic groups were 36-42% higher. Riboflavin remained at 18-19% because of the reasons previously discussed.

A comparison of consumption of both PCF and WF for 1991 and 1995, a few years after the decree, is equally positive for vitamin A and iron. The per capita

Iron and Vitamin A Provided by Consumption of PCF and WF for Lower Socio-economic Strata



Prior to fortification, no vitamin A was provided by PCF and WF and only 11% of RDA for iron. Although total consumption of PCF and WF remained relatively constant, by 1995, after fortification, consumers were receiving 33% of the RDA for vitamin A and 48% of the RDA for iron from these flour products.

consumption of 88.9 g/day of PCF and 37.8 g/day of WF offered zero of the RDA for vitamin A and only 11% of the RDA for iron. A few years later, in 1995, the average consumption of 100g/day PCF and 20.4 g/day WF is responsible for 33% of the RDA for vitamin A and for approximately 48% of the RDA for iron. Thus, even though consumption in general was not modified, improvement in nutritional status of the lower economic strata population has been demonstrated.

This impact is confirmed in a preliminary survey carried out in Caracas in 1994 in a population of 307 children aged 7, 11 and 15 years. Using serum ferritin as the indicator of IDA, the survey found that the prevalence of anemia was reduced from 37% in 1992 to 15% in 1994. The fortification program for PCF and WF was initiated and in force by mid 1993 and no other intervention program took place in that time.

Cost

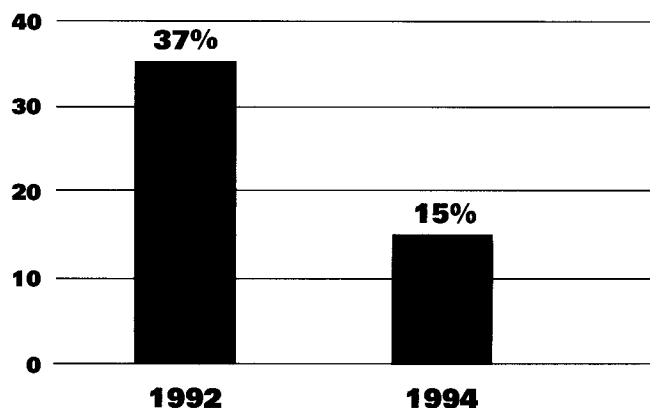
The cost of fortification of PCF and WF in Venezuela is very low. The cost of the vitamin-iron premix added to PCF is \$ 0.67 per metric ton and \$ 0.25 per metric ton of WF. At current average consumption, this translates into \$0.10 per person per year. At present, PCF is sold at approximately \$ 0.88 per kg. An average of 20 *arepas* can be prepared with 1 kg of PCF.

Lessons Learned

There are a number of factors which contributed to the preliminary success of the nationwide fortification of PCF and WF. First, for Venezuela, PCF and WF met the criteria for ideal fortification vehicles because they are staple foods regularly consumed in relatively constant amounts by the overall population. Consensus for concrete action was made possible through the creation by official decree of the Commission for Nutritional Food Enrichment (CENA). Presided over by the Director of the National Institute of Nutrition, CENA played a key role by providing a platform for dialogue among the government, industry and other involved sectors.

A direct intervention by the President, the sustained support of the Director of the National Institute of Nutrition, expertise of the technical staff as well as broad backing by well-known and respected Venezuelan leaders in human nutrition were all of decisive importance in the consolidation of the fortification program. Support from the wheat industry and representative segments of the corn processors was likewise crucial. The Venezuelan

Anemia Among Children in Caracas



A study using serum ferritin as an indicator found the prevalence of anemia among children dropped significantly during a period when no intervention occurred other than PCF and WF fortification.

Chamber of the Food Industry (CAVIDEA), sponsored a key conference attended by international and national decision makers from nutrition, food science, government and business communities. These were critical in building consensus on the feasibility of the program. Finally, an open and continuous debate in the media contributed to a balance of opinion.

There are a number of useful lessons that can be derived from the Venezuelan experience. First, the program should be broad-based with a national multi-sectoral commitment, not just with the government or with a political sector. The involvement of industry is crucial. In our case the strong support and participation of industry was made possible thanks mainly to the coordinated work of the CENA. Through that multi-sectoral communication platform we were able to reach the social conscience of the modern industrial managers and gain the full cooperation of the industry. It is an example of sustained team work between industry and the public sector representing a participative working model of formulation, decisions, design, control and adjustments. Finally, a multi-sectoral consensus was reached in regard to the fortification profile.

It should be noted that the actual fortification profile for both PCF and WF may be modified depending upon the results of the surveys which are monitoring the effect of these measures on the nutritional status of the population. It is a dynamic process.

The Progress of Wheat Flour Fortification with Vitamin A in the Philippines

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Abstract *Wheat flour-based products are consumed regularly by more than 90% of Filipinos, making this an ideal fortification vehicle to address a national vitamin A deficiency problem. While millers have expressed concerns about increased costs and sensory changes in the flour brought on by fortification, an alliance of NGOs, government agencies and donor organizations together with national millers and bakers associations are working together to overcome these barriers and provide bread that contains up to 30% of the RDA for vitamin A per serving.*

Background

Vitamin A deficiency, evident as both xerophthalmia and hyporetinemia, is a well-known public health problem among preschool children in the Philippines. The recent National Nutrition Survey (NNS, 1993) conducted by the Food and Nutrition Research Institute (FNRI) showed that 11 out of 15 regions in the country had significant levels of subclinical ($<20\mu\text{gRE/dl}$) VAD among preschool children.

The low dietary intake of vitamin A has been cited as a primary cause of VAD. Based on the FNRI survey, the average per capita intake of vitamin A is $327.9\mu\text{g RE}$ among rural inhabitants and $279.9\mu\text{g RE}$ among households in the lowest income quartile, equivalent to 73.8% and 63.6% nutrient adequacy ratio, respectively. The same survey and three other previous nutrition surveys also reported a low-fat intake across the population which was likely to decrease the bioavailability of provitamin A carotenoids.

The Philippine Plan of Action for Nutrition (PPAN) implemented a four-year nationwide vitamin A supplementation program among one-to six-year-old children, as well as various methods of targeted nutrition education. PPAN also mandated a food-based approach through food security measures and food fortification of wheat flour, oil, sugar and salt. Previously, only vitamin A-fortified oil-based margarine and iodized salt had gone to program scale. Vitamin A-fortified sugar was

supposed to be marketed by the biggest sugar producer in the country, but economic problems that beset the company had indefinitely postponed the implementation of the project.

Wheat Flour Production and Consumption

Wheat flour appears to meet many of the criteria for food fortification, among which is the increasing consumption and importation of wheat flour. All wheat grains milled in the country are imported. Wheat importation rose by 160%, from 1.3 million metric tons (MT) in 1989 to 2.1 million MT in 1994. All wheat is milled into flour by the country's 12 millers. Of these millers, seven are found in Metro Manila, two in Luzon, three in Visayas and two in Mindanao. Their strategic locations allow an adequate supply of wheat flour across all regions in the country.

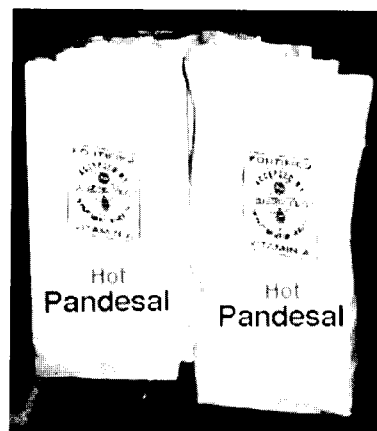
About 60% of the total imported wheat grains are of the hard type with more gluten and 40% are of the soft type with less gluten. About 33% of the hard wheat type is made into *pandesal* bread, 25% into loaf bread, 20% into bread rolls and 18% into noodles, which are a blend of 70% hard flour and 30% soft flour. Soft flour is used in the preparation of biscuits, crackers, cakes, pastries, pasta and noodles.

Pandesal, which is the most popular bread among Filipinos, is consumed by an average of 22.72% of households. As such, *pandesal* belongs to the first 25 food items

most commonly consumed by Filipino households.

In a survey conducted by the Nutrition Center of the Philippines (NCP, 1993) among school children in three rural villages in Luzon, it was found that 57% of the children (n=560) consumed wheat flour products in the form of bread. In particular, *pandesal* was consumed by 47% of the children. The mean one-day consumption of *pandesal* was 40 grams and that of other breads was 56 grams.

The University of the Philippines College of Home Economics study among randomly selected depressed households (n=600) showed that wheat flour products such as bread, biscuits and snack foods were consumed by 91%, 77% and 61% of the households, respectively. In particular, bread products were consumed daily or four to six times per week by 54% of the households. The average flour product intakes were found to be 47g for preschool children, 64g for pregnant women and 51g for lactating women



Pandesal, made with white flour, is the most popular bread in the Philippines.

Technical Considerations

In 1960, UNICEF was the first to realize flour's potential as a vehicle for vitamin A fortification. The United States government, responding to the call of UNICEF to fortify wheat flour with vitamin A, issued a regulation prescribing the incorporation of vitamin A into the flour sent to developing countries. Thus, all wheat (and other grain) flour exported by the U.S. under Public Law 480 was fortified with 2,200 IU-2,645 IU vitamin A per 100 grams, but their consumption and impact on vitamin A status in high-risk populations is unknown.

Since then, the stability of vitamin A and the retention of its biopotency during storage at various lengths of time and temperature have been documented in several studies in the laboratory and in actual practice. Vitamin A retention in low extraction wheat flour exceeded 95% for up to one year under a temperature of $\geq 40^{\circ}\text{C}$. Approximately 70% of vitamin A activity remained after baking traditional bread products with fortified flour.

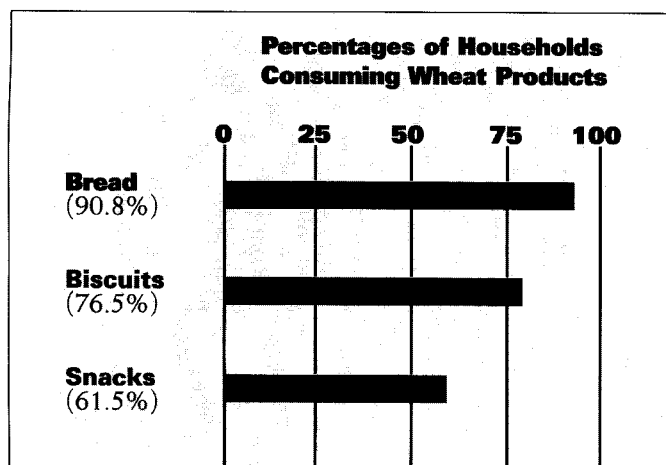
Bread baking trials in Jordan and India demonstrated conclusively that the destruction of vitamin A through the baking process for the preparation of bread was negligible. Multivitamin-iron premix, which contains 22.7% dry vitamin A palmitate type 250-SD (spray dried), was added to flour. Results showed that the organoleptic properties of the bread were maintained. Moreover, the vitamin-iron premix had excellent stability of vitamin A (100%) after six months of storage at room temperature. In Indonesia, breastfeeding women fed with beta carotene-enriched wafer for three months had increased serum retinol levels, breastmilk retinol and serum beta carotene after the intervention. These studies proved that vitamin A has been successfully added to wheat flour and bread.

Relationship of Intake of Flour Products with VAD

Mean one-day per capita intake of wheat flour products (gm)		
Prevalence of deficient* serum vitamin A levels among 6 month- 6 year old children		
Region		
National Capital Region	13.3	40
Ilocos	20.8	15
Cagayan Valley	3.4	20
Central Luzon	14.4	24
Southern Tagalog	12.2	32
Bicol	12.0	23
Western Visayas	3.4	12
Central Visayas	3.5	17
Eastern Visayas	5.3	20
Western Mindanao	20.3	12
Northern Mindanao	7.8	13
Southern Mindanao	8.1	11
Central Mindanao	3.3	10
Cordillera Administrative Region	12.6	23
Autonomous Region of Mindanao	8.5	20

* The WHO cut-off point for a public health problem is 5%.

Consumption of Wheat Products in Philippines



The average intakes were 42.3g preschool children, 71.8g for pregnant women and 51.8 for lactating women.

Advocacy

The National Micronutrient Action Team (NMAT) under the National Nutrition Council (NNC), the highest policy making body for nutrition, has been asked to formulate and implement micronutrient programs. As an initial move to implement the wheat flour fortification program, NMAT, together with the Department of Health (DOH) and the NCP – a non-government organization – conducted a consultative meeting with two organizations of flour millers, namely the Philippine Association of Flour Millers, Inc. (PAFMIL) and the Chamber of Philippine Flour Millers (CPFM). The meeting served as an opportunity for the flour millers to learn about the micronutrient problems in the country and the programs of the government to alleviate these problems. Emphasis was given to food fortification, particularly wheat flour fortification, as a means to combat micronutrient malnutrition.

Partnership with Industry

The industry's two main concerns were the increased cost of wheat flour products and the possible sensory changes that would result from the fortification of flour with vitamin A. The nutrition community addressed the millers' concerns by conducting a study on the retention and stability of vitamin A in flour and in the country's most popular bread, *pandesal*, as well as the organoleptic changes in the flour and *pandesal* after fortification.

The initiative from the DOH and the NCP won the cooperation and participation of two flour millers – Republic Flour Mills (RFM) and Morning Star Milling Corporation (MSMC). These two flour millers represented

the PAFMIL and the CPFM. The flour millers donated the flour needed for the study and allowed their facilities to be used. Two countryside bakeries – Napay and Sandes – baked the *pandesal* needed for the study.

International and Local Collaboration

NCP, as principal investigator, invited other government and non-government agencies to participate in the undertaking. UNICEF, Helen Keller International (HKI), IMPACT Foundation-Philippines and Roche-Philippines, collaborated in the conduct of the study. The Opportunities for Micronutrient Interventions (OMNI), Bureau of Food and Drugs (BFAD), Food Development Center (FDC), Roche Philippines and Switzerland, and the Asian Baking Institute (ABI) all provided technical assistance to the study. These concerted efforts highlighted the importance of wheat flour fortification before the scientific community, the government and the food industry.

Methods and Results

The study determined the retention and stability of vitamin A in flour and in baked *pandesal*, as well as the sensory changes in the flour and in *pandesal* over time.

The vitamin A fortificant used was dry vitamin A palmitate type 250-SD. The recommended level of fortification is 375 µg RE per 100 grams of flour with low extraction rate. Since there is an expected loss of about 30-40% during the milling and baking process, a 30% allowance was added to come up with a final level of 490 µg RE per 100 grams of flour. The vitamin A was mixed in the flour by the participating flour millers, RFM and MSMC.

Flour fortification at RFM was carried out by batch preparation. The 24.375 g of fortificant was added to 1 kg of flour and mixed using an ordinary mixer to make a premix flour. This premix flour was then added to 49 kg of flour in a ribbon blender and mixed for 15 minutes to make a preblend flour. Afterwards, this mixture was added to 13 bags (325 kg) of flour in the Patterson Kelly V-shaped blender and mixed for another 20 minutes.

At MSMC, 767.32 g of the fortificant was added to 4.2 kg of untreated wheat flour. This mix was blended for five minutes using the Kitchen Aid mixer equipped with paddle to make 5 kg of premix. The premix was loaded to a microfeeder and fed to the stream of flour at a rate of 60 g premix per minute. Vitamin A addition was through an acrison crew device in a continuous milling operation at the final stage of processing. The

flour stream flow rate is 141.66 kg of flour per minute. Flour rate was adjusted by a gravimetric and digital adjustment.

Fifteen sacks of vitamin A-fortified and 15 sacks of non-fortified flour were collected from each of the two millers. From month 0 to month 2, duplicate composite samples were taken from each set of 15 sacks and sent to the Food Development Center (FDC) laboratory in the Philippines and to the Roche Laboratory in Switzerland, which served as the reference laboratory. The two laboratories conducted vitamin A assays on the samples with the use of high performance liquid chromatography (HPLC) method.

The fortified flour from the two millers was used in baking *pandesal* by the two countryside bakeries and by the ABI, which served as the reference bakery. Duplicate *pandesal* samples from each bakery were used for sensory tests at the FDC.

Prior to the selection of FDC as reference laboratory, an expert on HPLC conduct was requested to evaluate the capability of three local laboratories, namely FDC, Societe General de Surveillance (SGS) Philippines and the Bureau of Food and Drugs (BFAD). The results showed that all the laboratories were capable of conducting HPLC. FDC was chosen, however, because it could also conduct the sensory tests needed for the study.

The mean results from the two mills showed that from the original amount of 490 µg RE added to the flour (month 0), FDC recovered 314 µg RE or 64% of the vitamin A, while Roche recovered 380 µg RE or 78% of the vitamin A (coefficient of variation = 13.45%). Based on FDC results, the fortified flour stored at room temperature (27-30°C) for one month retained 81% (256 µg RE) of the vitamin A and at two months 66%

Mean and Percentage Retention of Vitamin A in Fortified Flour and Pandesal

Time (month)	Flour (RE/100g)	Pandesal (RE/100g)	% Retention
0	314.4	284.8	90.6
1	255.8	205.3	80.3
2	208.8	148.9	71.3
3	173.0	110.8	64.0

In the Philippines flour is usually not stored for more than 1 month to prevent spoilage.

Additional Cost of Fortification to the Price of Flour and Pandesal Bread

Unit	Flour Price	Unit	Pandesal Price
per kilo	P 0.088	per piece (30g)	P 0.0017
per sack (25kg)	P 2.20	per serving (60g)	P 0.0034
Per ton (1,000kg)	P 88.00		

The P 0.088 cost of fortificant translates to USD \$.00338. Moreover, the two distributors of vitamin A in the Philippines are considering an adjustment which would drive the additional expense of fortification even lower.

(208 µg RE). No adjustment was made to account for the decreased potency (about 15% or 490 µg RE less 74 µg RE/age of fortificant) of the fortificant before it was added. The non-fortified (control) wheat flour contained no trace of vitamin A. The FDC results were found to be more conservative considering that they conducted vitamin A assay on flour and bread by HPLC for the first time.

The mean amount of vitamin A retained in the *pandesal* (baked at 375 °F for 10-15 minutes) from the three bakeries at month 0 was 284 µg RE (90% of 314 µg RE) and at month 1, 205 µg RE (80% of 256 µg RE). *Pandesal* baked from fortified flour two months after fortification retained 71% of 208 µg RE (148 µg RE). The amount of loss was associated with the age of the flour. However, in the Philippines, flour is usually not stored for more than one month to prevent spoilage. The *pandesal* baked from non-fortified flour also contained no trace of vitamin A.

The color and odor of the flour did not change significantly within one month after fortification. Likewise, the taste test showed no difference in the flavor of *pandesal* prepared from flour aged month 0.

One serving (two pieces or ~50 grams) of the fortified *pandesal* contained about 80-111 µg RE of vitamin A. This provides 15-30% of the recommended daily allowance (RDA) of children for vitamin A. In the 1993 NNS, the average gap of the RDA for vitamin A intake was ~26% in rural, and ~12% in urban areas.

The study proved that after fortification, the vitamin A recovered and retained in flour stored for one month as well as in baked *pandesal* was substantial enough to improve the vitamin A intake of the population, assuming ~80-90% absorption of the vitamin A palmitate.

The added cost of fortificant per kilo of flour was less than 10 centavos (P 0.088 or \$0.00338). The additional cost to one piece of pandesal which contains 20.4g of flour is P 0.0017 or \$0.00006. No expenses were incurred for the purchase of equipment or other materials.

Government Action

The results of the study were presented to the collaborators, funders and the NNC Governing Board, which endorsed the wheat flour fortification program to the owners. A series of meetings with the flour millers' and bakers' associations was organized by NNC to advocate the fortification program. The meetings were also attended by representatives from government agencies, non-government organizations and other concerned sectors. In the initial meetings, the Secretary of Agriculture and Chairman of the NNC appealed for the millers' participation in the government's efforts to combat micronutrient malnutrition, in particular VAD.

Millers' Concerns

The additional cost of fortifying wheat flour would come only from the cost of the vitamin A fortificant. There would be no need for additional equipment or utensils as the vitamin A premix may be fed conveniently through the volumetric feeder which is also used for adding other micronutrients to flour. Nevertheless, the millers reiterated their concern about the additional

cost of fortification. Although it appeared that the additional cost per kilogram of flour was minimal, the total cost would be significantly high enough if the millers' annual production was considered. The cost of the fortificant is about P88.00 or US\$3.34 per metric ton.

To distribute the cost equitably, the NNC chairman proposed to make the thousands of bakers absorb the cost of fortificant. The other option was to subsume the cost of fortificant in the annual price increase in flour as dictated by the world market as well as other reasons such as inflation. In the Philippines, the average yearly increase for four successive years in the price of a 25-kg bag of flour was US\$2.

A market test was also proposed by the millers to determine the economic viability of fortifying wheat flour with vitamin A. One flour miller from each of the flour millers' associations would be asked to participate in a six-month market test. The expenses to be incurred would be shouldered by all the members of the respective associations. Since there would be a price difference between non-fortified and fortified flour, the dealers and/or bakers were likely to buy the non-fortified flour, thereby defeating the purpose of determining the marketability of fortified flour. Experience in the local flour market has shown that a one-peso flour price difference would cause a buying shift to the lower priced flour. This was a definite disadvantage to those who would produce fortified flour.

Since the millers were apprehensive about pursuing the wheat flour fortification program because of the additional costs that would be incurred, a meeting with the bakers' associations was held to determine the response of the bakers to this issue.

Bakers' Response

The bakers, belonging to the Philippine Federation of Bakers Association, the Metro Manila Bakers Association, and the Filipino-Chinese Bakers Association Incorporated, welcomed the proposal to fortify wheat flour with vitamin A. According to them, this would give *pandesal* a good image, increase its consumption and sales, and allay the fears of the consumers aroused by the recent potassium bromate issue. The ban on the use of potassium bromate as a maturing agent in flour and improver in bread products was recommended by the World Health Organization because of the carcinogenic property of the chemical. The DOH had implemented the ban on the use of potassium bromate on bread. The fortification

Annual Wheat Flour Production and Projected Cost of Fortificant by Miller, 1996

Flour Miller	Annual Production (MT)	Volume of hard wheat flour to fortify (MT)	Cost of fortificant (pesos)
Morning Star Milling	75,000	45,000	3,472,389.00
Foremost Milling	18,000	10,800	833,373.36
Purefoods Corporation	200,000	120,000	9,259,704.00
RFM Corporation	187,500	112,500	8,680,972.50
General Milling Corp.	540,000	324,000	25,001,200.80
Liberty Flour Mills	105,000	63,000	4,861,344.60
Pacific Flour Mills	75,000	45,000	3,472,389.00
PHILMICO	125,000	75,000	5,787,315.00
Philippine Flour Mills	90,000	54,000	4,166,866.80

Note: Only 9 flour millers were able to provide data on their annual production.

program thus came at an opportune time to protect the image of *pandesal*.

The bakers agreed to absorb the cost of the fortificant by buying the vitamin A-fortified flour at an increased price. Likewise, the bakers committed to share in the publishing and dissemination of the advertisements for fortified *pandesal*. The bakers group was willing to support the market test proposed by the millers. However, the bakers urged the millers to put their heads together and agree on fortifying wheat flour with vitamin A.

Initially, some millers planned to produce vitamin A-fortified flour to cater to thousands of bakers who had expressed willingness to buy such flour. However, the bakers were worried about the possibility that the limited number of millers producing fortified flour would not be able to supply the demand. With the granting of the *Sanghap Pinoy* seal from the DOH for properly fortified foods, more bakers may be inclined to buy fortified flour.

As an offshoot of continuing discussions on the issues of flour fortification, Mr. Donut company in the Philippines requested assistance from NCP in fortifying the flour used in baking doughnuts. Encouraged by the results of the NCP study on the fortification of wheat flour with vitamin A, the company, on its own initiative, is now fortifying its doughnut products with vitamin A. The company adds the vitamin A fortificant to the flour it buys from millers and uses the fortified flour in baking varieties of doughnuts sold in most cities and towns all over the country. Lower-priced *junior donut* versions of the vitamin-A fortified doughnuts are especially made to cater to children.

Problems will not be encountered if all the flour millers fortify flour with vitamin A. The flour dealers and bakers, who are the main buyers of flour, will then have no option but to buy fortified flour. The additional cost will be the same across all flour millers. If there is still any price difference, this may be due to factors other than flour fortification.

Support From Various Sectors

The government expressed its commitment to support the promotion of vitamin A-fortified *pandesal* through massive tri-media campaigns. In particular, the DOH was willing to allow the fortified *pandesal* to carry the *Sanghap Pinoy* seal (SPS) for vitamin A as a means to

promote it. The *pandesal* should, however, meet the requirements for the SPS program.

In addition, the NCP and the Philippine Institute of Pure and Applied Chemistry (PIPAC), with funding support from OMNI, developed an analytical method for the in-plant monitoring of vitamin A in fortified flour. This was in response to the request for the establishment of a quality assurance system in the production of fortified flour by the research and development staff of the mills. An interlaboratory test on the spectrophotometric method was conducted among ten laboratories in the country to support the millers' needs.

The results of the NCP study on the fortification of wheat flour with vitamin A were also presented to members of academia who had been active in the government fortification program. This led to the endorsement of wheat flour fortification with vitamin A by the deans and directors of the National Institutes of Health (NIH) and all the member-pediatricians of the Child Health and Development Sector of the NIH of the University of the Philippines, Manila.

Two distributors of vitamin A fortificant have considered adjusting the cost of the fortificant to benefit the wheat flour fortification program.

A field trial to determine the effect of vitamin A-fortified *pandesal* on the vitamin-A status of rural school children is being undertaken by NCP, HKI and Johns Hopkins University with funding support from OMNI.

In the Philippines, the daily per capita intake of food products made from flour is expected to continue rising over the next two decades. Recent studies show that in Southern Luzon alone, about 40% of children eat *pandesal* for breakfast. The daily per capita intake of preschoolers is about 60 g while that of school-age children is about 85 g. Thus, the dream of the nationwide fortification of wheat flour with vitamin A is waiting to be fulfilled.

With all the collaborative efforts from various sectors despite the challenges ahead, a major part of the work on the fortification of wheat flour with vitamin A has already been done. Most of the work needed in the national food fortification program is also underway. The government and the private sector must now keep the momentum going towards the realization of the nationwide fortification of wheat flour with vitamin A.

Triple Fortification: Instant Noodles

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Abstract *Since Thailand is facing problems of micronutrient deficiencies of iodine, iron and vitamin A, in 1994 a Ministry of Public Health Committee proposed a feasibility project for micronutrient fortification of instant noodles seasoning. This project was jointly undertaken by academic, government and private sectors. Micronutrient dosages per serving represent one-third of the Thai RDI for iron, iodine and vitamin A. Project results showed that a premix containing potassium iodide, encapsulated reduced iron and vitamin A remains stable under accelerated and normal storage conditions with no adverse effects on the sensory qualities of most products. Information concerning the fortified nutrients, types and brands of the fortified product was publicized through the media with support from instant noodles manufacturers and a ministerial committee.*

Introduction

While protein energy malnutrition (PEM) in Thailand has lessened in severity over the past ten years, micronutrient deficiencies of iodine, iron and vitamin A are still significant problems. Though many prevention and control strategies have been implemented, fortification of industrially processed foods is now emerging as one potentially important strategy due to the growing reliance on such foods by the Thai people. This has arisen out of the country's rapidly expanding, industrialized and cash-based market economy. Industrially processed instant noodles seem to be a suitable vehicle for micronutrient fortification, since the product has desirable sensory qualities, is acceptable and readily available, and also is affordable by all groups in Thailand.

Micronutrient Deficiency Problems in Thailand

Micronutrient malnutrition can take a heavy toll through loss of productivity, vitality and initiative. In Thailand, iodine deficiency disorders (IDD) have affected many people due to an increase in deforestation and topsoil erosion. In 1995 goiter in primary school children averaged about 5.7%. The highest prevalence was found in the northern part of the country, which averaged about 7.6%, while the prevalence in one province was as high

as 28%. Prevalence in primary school children in other areas of the country ranged from 2.0 to 6.8%. To combat the IDD problem in endemic areas, household, community and school drinking water supplies have been supplemented with potassium iodate solution for the past few years. Since 1994 it has become mandatory for table salt in Thailand to be fortified with either potassium iodate or potassium iodide at 50 ppm. Community-produced salt, which is normally consumed among the target populations, usually cannot be fortified within such a standard due to low technology and low-quality salt. Thus, despite all efforts, IDD persists as a significant public health problem.

Iron deficiency is found among children and pregnant women. The highest prevalence in the past was attributed to hookworm infestation in the southern part of Thailand. However, the problem is now widespread throughout the country.

A survey in 1991 indicated that the prevalence of anemia in preschool children ranged from 11.9 to 21.7%. In 1995 anemia among primary school children in all parts of the country was 12.2 to 20.4%, while in pregnant women it ranged from 8.8 to 16.7%. Current prevention strategies aim at provision of iron tablets to pregnant woman, although the impact of such supple-

mentation is limited by difficulties of compliance and promotion of consumption of iron-rich foods by children.

The World Health Organization does not classify Thailand as a country where vitamin A deficiency (VAD) is a public health problem. However, subclinical cases are sporadically found in many rural areas. In 1995 moderate subclinical VAD in preschool children was estimated at about 20%, as exhibited by inadequate liver stores of vitamin A and low serum retinol levels. This situation has improved since 1992, when active xerophthalmia, inadequate liver stores of vitamin A and low serum retinol cases were found as high as 0.43, 56 and 11%, respectively, in southern Thailand. Such an improvement has been the combined result of a vitamin A capsule supplementation program in the area, increasing the production and consumption of vitamin A-rich foods and a government regulation to fortify sweetened condensed milk—sometimes used as a breast milk substitute or infant formula by the poor—with vitamin A. This regulation was filed by the Thai Food and Drug Administration in 1994, and the fortification level is 330 mg retinol per 100g.

Government-Industry-Academic Partnership

Based on the 1992 World Declaration and Plan of Action for Nutrition developed at the International Conference on Nutrition in Rome, Italy, Thailand's Ministry of Public Health appointed an advisory working committee in 1993 to increase the "cooperation of government and private sectors in solving food and nutrition problems in the country." The committee consisted of representatives from the Ministry of Public Health, Ministry of Agriculture and Cooperatives, the Federation of Thai Industries, and the Institute of Nutrition, Mahidol University. Committee members agreed that it was impossible for the government sector alone to solve the nation's nutritional problems. Therefore, cooperation between government, industry and academia was strongly recommended. It was also decided that solving micronutrient deficiencies should be the urgent commitment of this committee and that fortification of industrial-processed foods with micronutrients should be pursued.

Instant Noodles Market in Thailand

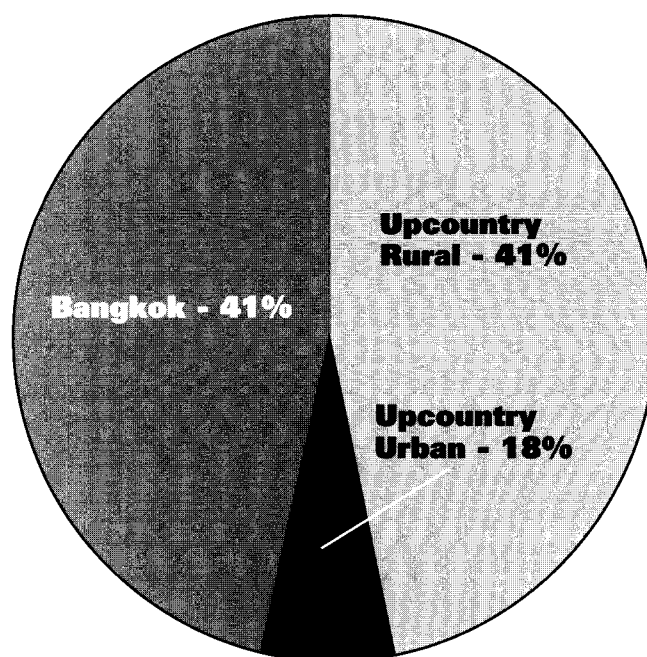
Instant noodles, sold in ready-to-prepare packaged form, are very popular among the industrial-processed foods in Thailand. Six million packages are produced daily, 80% of which are made by only three companies. Most are

consumed domestically, although they also are exported abroad, especially to neighboring countries. In 1993 instant noodle consumption in Thailand was 30 packs per capita. Over 90% of these instant noodles are of the deep-fried type, which is sometimes classified by academicians as "junk food" due to high salt, fat and carbohydrate content and low-quality protein. It is therefore recommended on the package to combine the noodles with meat or egg and vegetables, which is actually the traditional way of eating noodles. However, this suggestion is seldom practiced by consumers due to lack of time and to inconvenience.

Consumers of instant noodles in Thailand include males and females in the age group 15 to 49 years, from all socioeconomic strata. Forty-one percent of the products are consumed in Bangkok and a similar percentage in up-country rural areas.

The cost of a 55g package of instant noodles is only 3.50-4.00 baht (US\$ 0.14-0.16), while one serving of Thai fast food costs at least 10-15 baht (US\$ 0.50-0.60). The price of instant noodles was increased in October 1996 after it had been held at about 3.00 baht (US\$ 0.12) for almost 16 years. The price was previously fixed due to high market competition. Instant noodles are a low margin product, but can be distributed to consumers

Distribution of Instant Noodles Consumption



In Thailand 6 million packages of instant noodles are produced daily. 80% are produced by three companies.

throughout the country. The product also has acceptable sensory characteristics and good shelf stability. A variety of flavors is widely available both in original Chinese and traditional Thai styles. The shelf life of instant noodles is at least six months at an ambient temperature. The product is thus widely accepted throughout the country and has become a commodity of interest for micronutrient fortification.

Feasibility Study for Triple Fortification

In late 1994 the ministerial committee agreed that a feasibility study be undertaken on the triple fortification of instant noodles. The committee and instant noodles manufacturers planned for the seasoning packet to be fortified, since the seasoning powder does not need any cooking prior to consumption and is also well protected in a separate bag within the noodle package. To attract public interest in the project, the committee included it as an activity in the Golden Jubilee Celebrations of King Bhumipol's accession to the throne. Such planning automatically set the deadline for launching the product no later than December 1996. The fortification dosages for iodine, iron and vitamin A are 50 µg, 5 mg and 267 µg, respectively, which amount to one-third of the Thai Recommended Daily Intakes (Thai RDI).

This project is being conducted on a voluntary basis, and interested representatives of instant noodles manufacturers are jointly working with the committee members. For the feasibility study, information regarding the fortified products, such as the fortificant to be used, sensory acceptability, cost and shelf stability were evaluated as outlined below.

Selection of the Fortificants

A premix of potassium iodide, ferrous fumarate and vitamin A palmitate was initially tested with several flavors of instant noodles. Manufacturers found that some seasoning ingredients containing Chinese five spice powders, particularly nutmeg, reacted with ferrous fumarate, resulting in an unacceptable black-colored soup. Iron EDTA was also tested, yielding similar results. Finally, encapsulated iron, which is in a reduced form encapsulated with partially hydrogenated oil as the coating material, did not react with these spices nor with the seasoning powders. Therefore, the premix fortificants included potassium iodide, encapsulated iron and vitamin A palmitate, at a dosage level of 20 mg per package of instant noodles.



To attract public interest in the project, it was included as an activity in the Golden Jubilee Celebrations of King Bhumipol's accession to the throne.

Sensory Acceptability

After the premix was selected, a sensory discrimination test was performed in pork-flavored instant noodles. This product has the mildest flavor and any off-flavor caused by the fortificant can be easily detected. Results from the triangle test showed no significant difference in sensory qualities ($p > 0.05$) between the normal and fortified products. For color changes due to the reaction between the seasoning powders and the fortificant, a study was performed by observing color changes in cooked Pa-Lo duck-flavored instant noodles which contained Chinese Five Spice powder. Observations of both normal and fortified noodles were made every 5 minutes for a period of 30 minutes. The colors were slightly different on the Munsell™ color chart after 25 minutes. This period is, however, long enough for an average consumer to finish a bowl of noodles.

Cost

An increase in the cost of the fortified product arises directly from the premix. Within the next three years, the cost of the premix per serving of instant noodles will remain at not more than 0.02 baht (US\$ 0.08). This cost has actually been lowered due to the premix's special taxation rate, which has been reduced from 45% to 10% at the request of the Ministry of Public Health and a nutrient importer. Although the cost of fortifying instant noodles is not high, most instant noodles manufacturers still hesitated to join the program at the beginning, due to the low cost margin. However, since October 1996, instant noodles manufacturers have raised the prices of their products by 15 to 20%, which



Instant noodles, sold in ready-to-prepare packaged form, are very popular processed foods in Thailand.

it was concluded to the FDA that the fortification dosage should have an allowance of 20% based on the available mixing technology. In January 1997, Her Royal Highness Princess Maha Chakri Sirindhorn allowed the committee and instant noodles manufacturers to meet personally at the exhibition on triple fortification of instant noodles, which was held at the Institute of Nutrition, Mahidol University. After the meeting, five out of seven instant noodles manufacturers agreed to fortify at least one kind of their products. Presently, about 10% of the products in the market have been fortified.

Even though the effect of the fortificants on the quality and shelf life of seasoning powder have been shown to be insignificant in the acceleration tests done by both academicians and manufacturers, some manufacturers have still not been confident with the results. Some manufacturers, though, started to consider fortification of their products after the fortified products were on the market for six months, which is the normal shelf life of the products at normal storage conditions.

If necessary, academic advice or further research will be undertaken. The Institute of Nutrition, by providing academic input to the committee, is thus aiding in solving the technical problems in the program. Since there were complaints from manufacturers on the effect of fortificants on the sensory quality and moistness of seasoning powder, the institute undertook immediate testing

and found that the problem was due to the packaging and not the fortificants used. This has boosted encouragement among potential newcomers.

Marketing policies of some companies have also caused problems, since nutritive value is not their selling point and they do not recognize the necessity to fortify the products, especially when the program is voluntary. Some academicians and press who have not understood the concept of fortification have made very strong comments branding the fortified instant noodles as "make-up junk food". Hesitation in launching the product by the companies with a large market share caused the problem of "creation of demand without supply," since the program at the beginning was widely promoted via several media but the fortified products were not readily available in the market. The promotion was almost useless, and indicated failure of the program to the public.

Now about 10% of products have been fortified and more products are also being registered for fortification with the FDA. A gradual progress is thus observed in the program. In the beginning, program promotion was undertaken only by the committee, but now a manufacturer has made poster advertisements promoting nutrition as the selling point of their fortified product.

Furthermore, some manufacturers have also planned to have their exported products fortified. Such a plan will also benefit other developing countries in South and Southeast Asia that have the problem of micronutrient deficiencies.

Conclusion

A short-term metabolic study or field efficacy trial on the bioavailability of these fortificants in the target population should be undertaken in order to confirm the benefits of such fortification. Studies on long-term community effectiveness should also be performed to evaluate the cost-effectiveness of the program.

Successful cooperation among government, academic and industrial sectors can result in a so-called "win-win situation," which would mutually benefit all the parties. This project on the fortification of instant noodles is only an example of such cooperation. Expectedly, difficulties have been arising during operation, especially since the project is performed on a voluntary basis. However, once it becomes sustainable, consumers will be the main beneficiaries.

Rice Fortification: A Promising Technology for Micronutrient Deficiency Reduction

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Abstract *A main dietary staple in many countries, rice is an attractive vehicle for micronutrient fortification. However, a profusion of small millers as well as losses of fortificants during washing and cooking have proven to be major obstacles. Recently, fortification technology which can overcome these barriers was made available at no charge to national programs to end micronutrient malnutrition. Provincial market trials in Indonesia verified stability of vitamin A, validated mixing procedures for medium and small millers, and demonstrated consumer acceptance and feasibility of marketing through a variety of local outlets.*

Why Rice?

Rice, cultivated originally in India around 3000 B.C., is the second most common food consumed by man, next to wheat. Wheat, rice and maize are the three leading food crops in the world, together directly supplying more than 50% of all calories consumed by the entire human population. In terms of area harvested each year, wheat is the leader with 230 million acres, followed by wetland rice with roughly 145 million acres and by maize with 130 million acres. It is notable that while the volume of rice harvest is second to wheat, rice will feed more people than any other crop, since almost 20% of harvested wheat is fed to animals. Rice is consumed by an estimated half of the world's population in main and side dishes, soups, cakes, puddings and sake. Because of its long history of cultivation, rice is grown in different environments and with cropping methods ranging from primitive to modern.

Rice is the most adaptable of food grains. It is grown from as far north as Russia to as far south as Argentina; from the humid tropics of India, Indonesia and Malaysia to the semiarid dry lands of USA, Pakistan and Australia; and from the high, cool mountains of Nepal and Bhutan

to the low hot deserts of Iran and Egypt. It is grown and consumed in a great number of countries.

For the majority of Asians who eat rice, the grain accounts for a remarkably high proportion of total calorie intake. In Myanmar, for example, 73% of the total food energy value of the population is derived from rice, while in Thailand roughly two-thirds of the calories are provided by rice. In these countries a representative citizen eats about 160 kg of husked rice each year, or almost 0.5 kg per day. Rice supplies almost half of the total national calories in Madagascar, Liberia, Sierra Leone, Guinea, Ivory Coast, Surinam, and Guyana. While rice is not a major food for most of the people in the western world, it is eaten in substantial quantities by the immigrants to these countries from some other countries, notably Southeast Asia. Moreover, a vast majority of people rely on rice for their protein intake, and although it is inferior to animal protein, it is superior to the protein of other cereal grains. Other qualities of rice make it ideal for today's health-conscious and busy consumers. For instance, rice is low in sodium, is free from gluten and cholesterol, and adds fiber to the diet. It is easy to digest, thus its consumption is continued during

sickness and health. Preparation of rice for consumption is easy and takes little time, which is an important point considering women's heavy workload in most countries. Day to day consumption of rice is almost constant within each age group and sex and for all income and occupational categories of populations.

Why Fortification of Rice?

Rice is a main dietary staple for many micronutrient deficient populations suffering from both the deficiency of vitamins and minerals naturally present in the grain but removed during milling, and from the deficiency of those that are not naturally present in appreciable amounts. Most vitamins and minerals in the rice grain are in the bran and embryo, which are removed during



Unlike other cereals like wheat and corn, rice is consumed as a whole kernel and is not usually made into flour for consumption.

the process of milling or polishing rice; thus, for example, the thiamine content of the milled rice will be only 0.12 mg/100g in white polished rice compared to 0.54 mg/100g in brown rice.

For rice-eating populations suffering from deficiency of other micronutrients, rice can be singled out as the most suitable candidate for delivery of such micronutrients. Fortification and enrichment of rice can be a useful tool (1) to prevent development of nutrient deficiencies; (2) to eliminate existing nutrient deficiencies; and (3) to enhance quality of diet and improve nutritional status of a rice-eating population.

Examples of Rice Fortification in Some Countries

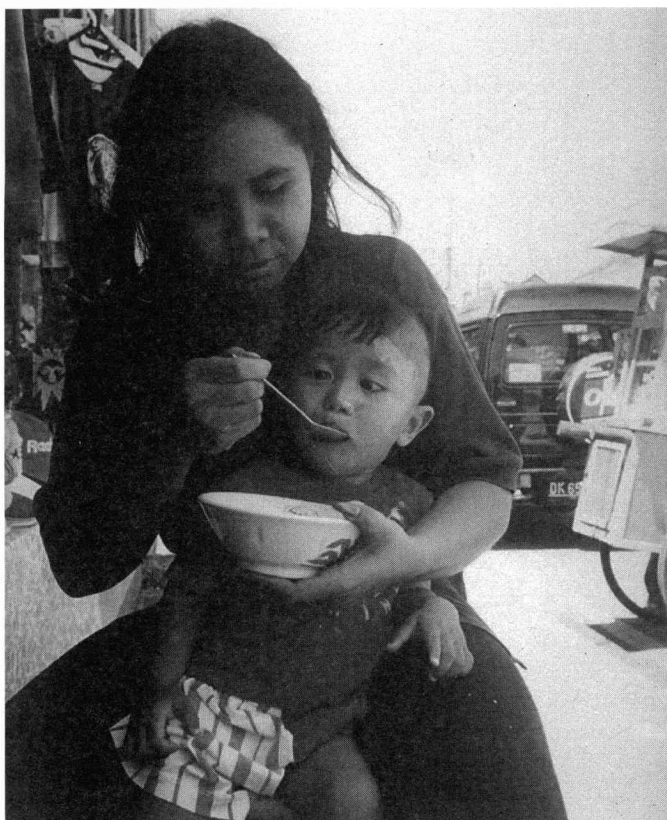
The following gives some examples of rice fortification activities around the world: In 1947, a disease called beri-beri, caused by thiamine deficiency, was responsible for 24,000 deaths in Bataan, the Philippines. Thiamine was added to rice, and after two years there were no deaths associated with thiamine deficiency. The first process for making a premix for rice enrichment was developed in Manila by an American company in 1950. Rice fortification in the Philippines was required by law in the 1950s. This, however, was enforced for less than a decade mainly because, based on the amount of premix rice producers and millers obtained from authorized premix distributors, the government was able to monitor their taxable income!

In Japan, thiamine enriched rice has been used for almost the last 50 years. In the USA, a law enacted in South Carolina permitted enrichment of rice in 1956 for the first time and prohibited the sale of ordinary white rice. This was then followed by other states. Today, most of the rice sold in the USA is enriched. In Canada, the addition to pre-cooked rice of B₁, B₆, folic acid, niacin, pantothenic acid and iron is permitted. In Papua, New Guinea, a formulation that includes iron and vitamin B is used. In Chile, there is already a product on the market using dry mixing technology. In Argentina, a rice mill has a product on the market produced using surface-coating technology.

Rice Fortification/Enrichment Technology

Unlike other vehicles used for delivery of micronutrients, such as salt, sugar or wheat grains, fortification of rice presents a different challenge. This is because, unlike other cereals like wheat and corn, rice is consumed as a whole kernel and is not usually made into flour for consumption. Added to this is the fact that rice is often washed thoroughly before cooking, and is, in many countries, usually cooked in excess water and drained; hence, two fortification premixes have been required: non-rinse and rinse-resistant types. Also problematic is the existence of many small-scale millers especially in developing countries, so that rice is not always centrally processed. As in the case of other vehicles used for fortification, uniformity of distribution of added nutrients and premixes is not always easy to achieve.

Overcoming these problems also has been delayed by the tendency for research to aim at perfecting fortification technologies for those grains that are most widely consumed in affluent countries. Thus, rather than



After the fortification of rice with thiamine in Bataan, the death rate from beri-beri went from 24,000 in 1947 to zero two years later.

employing rice as a vehicle to deliver micronutrients to a deficient diet, the earlier fortification technology for rice focused on reserving nutrients and restoring vitamins and minerals lost during milling and processing of rice grains. Processes such as undermilling and parboiling received a lot of attention in the 1930s and only more recently other technologies have been developed for rice fortification. These are briefly discussed below.

Parboiled Rice

For many years this has been a well-known method of rice enrichment. Traditionally, parboiling is done by soaking rough rice in a jar of water to which heat is applied. The grains are then dried in the sun and milled. This results in transferring into the endosperm 50-90% of the vitamin in the embryo and bran. Parboiling was seen as a useful method to prevent vermin damage, thereby increasing storage suitability. The process makes threshing easy and prevents rice grains breaking during milling. The golden color and an earthy woody flavor, however, lowered consumer acceptance of the resultant product.

Converted Rice

Huzenlaub (1935) and others have described improvements of the process to make parboiled rice, and have produced what was known as enriched converted rice. Basically, the process involves removing the air contained in rough or brown rice in a vacuum chamber, then soaking rice grains in a hot water bath and applying pressure to cause vitamins and inorganic matter in the bran to transfer into the endosperm. Rice is then steamed in a rotary steam kettle, cooled and hulled. This results in a hard gelatinous film to be formed on the surface of each grain, which reduces the loss of vitamins through washing. A year later, Gibbon (1936) introduced his method in which, as described by Misaki and Yasumatsu (1985), rice is provisionally dipped in warm water, then kept at a temperature below zero for 5 to 10 minutes, heated again and dried. The resultant enriched rice is characterized by freedom from vermin damage, and is thus suitable for storage. The disadvantages are slight discoloration and an undesirable odor obtained in the course of processing.

Acid-Parboiled Rice

To make enriched rice agreeable to the taste of Japanese people, Kondo et al (1949, 1950, 1951) manufactured enriched rice by adding acetic acid to the soaking water. This improved the taste of the final product.

Gradually, it was recognized that rice can be utilized as a carrier for micronutrients where dietary deficiencies of such micronutrients exist. Subsequent to this realization, some research activities were undertaken to develop the necessary processes and methodologies for fortification of rice grains with micronutrients.

Surface Coating Method

In this method, developed from the research of R.R. Williams and co-workers, who synthesized thiamine for the first time, milled rice is placed in a rotary cylinder. While the cylinder is rotating, the grains are sprayed with a solution containing vitamins and minerals and then hot air is blown in to dry them. Then, a protective coating which does not dissolve in cold water but does dissolve in water above 70°C is applied to prevent the loss of nutrients through washing and to distribute the added nutrients evenly by cooking. After drying, talc and ferric pyrophosphate are added to keep the grains from sticking together.

Another method is used to fortify rice with iron in the Philippines to control and prevent iron deficiency

anemia. In this process a suspension of the fortificant is sprayed on to clean, polished rice as it is tumbled in a large rotating cylinder as described by Solon and Pedro (1991). After evaporation of the solvent, a relatively soluble coating on the rice grains is left. The fortified rice grain is then encapsulated with a coating material to prevent discoloration and off-flavors that may result from the use of ferrous sulfate as well as to minimize the washing off of the fortificant prior to cooking. However, there may still be micronutrient losses if rice grains are cooked in excess water and drained, which is a practice in many rice-eating cultures.

Mixing at the Time of Cooking

To increase micronutrient intake of a rice-eating group, another suggested strategy was enriching rice by adding the required amounts of nutrients at the time of cooking. In this process, a mixture of nutrients in powdered or tablet form is dissolved in water and the solution is added during rice cooking. The method is economical and has the advantage of allowing for easy adjustment of the nutrient content. This novel method seems to be more suitable for mass cooking such as for school or factory lunches where monitoring the amounts added is more practical.

Artificial Rice

In this method, fortified rice grains are first produced and then mixed with ordinary milled rice. The so-called faked grains are made by adding the micronutrients to rice flour, forming a dough that is then extruded with equipment similar to noodle manufacturing before these are mixed with the ordinary grains. Here, the kinds and amounts of nutrient to be incorporated can be easily controlled, but due to the interactions among various nutrients added, there may be micronutrient losses, and the end product may be visibly different from the ordinary rice with which it is mixed. Thus, earlier attempts to utilize this novel technique tended to produce visibly different grains with a poor appearance after cooking. A significant improvement in the technology resulted in creation of a product named Ultra Rice which was a vitamin A-fortified rice product briefly described below.

A synthetic rice composed of rice flour and other ingredients extruded through a dry pasta machine was developed by Bon Dente Co. Lynden, in Washington. Vitamin A Palmitate 250 SD was determined to be the most chemically stable. The Ultra Rice is made by

Rice Fortification Technology

Parboiled Rice

Soak rough rice in water, apply heat, dry grains in sun and mill. Vitamins are transferred into endosperm.

Converted Rice

Remove air in rough or brown rice in vacuum chamber, soak grains in hot water, apply pressure to cause vitamins to transfer to endosperm. Steam, cook, and hull rice.

Acid-Parboiled Rice

Add acetic acid to soaking water to improve taste.

Surface Coating

Rotate milled rice in cylinder while spraying grains with vitamins, dry grains with hot air, apply protective coating, talc and ferric pyrophosphate to prevent sticking.

Artificial Rice

Produce fortified rice grains by adding micronutrients to rice flour and extruding grains, then mix artificial grains with ordinary milled rice.

Mixing Nutrients at Time of Cooking

Dissolve mix of nutrients in powdered or tablet form in water and add during cooking.

Ultra Rice

Make synthetic rice using rice flour and other ingredients, then extrude paste through dry pasta machine.

blending the fortificant into rice flour and extruding the paste made to yield a concentrated fortified rice product that has the appearance, density and taste of unfortified rice. The concentrate, with a typical vitamin A content of approximately 2500 IU/g, can then be blended with unfortified rice at ratios from 1:100 to 1:200 to provide an appropriate dietary level of vitamin A. The size and shape of the concentrated grain can be adjusted to blend with the type of rice being fortified.

The product was subjected to accelerated storage studies to simulate the temperature and humidity conditions in the Philippines. Washing stability, cooking stability and color were evaluated. Feasibility trials with the Ultra Rice fortified with vitamin A were successfully conducted in Brazil.

The source of the rice flour can be milled broken rice grains, which account for 15-50% of the world's rice

The Ultra Rice is made by blending the fortificant into rice flour and extruding the paste made to yield a concentrated fortified rice product that has the appearance, density and taste of unfortified rice.

harvest, depending on the region. Broken rice grains lower the value of the rice and, therefore, are often sorted out and sold to brewers or as animal feed. Use of the broken grains for production of fortified rice, therefore, represents a secondary benefit as a way to increase overall rice yields.

Although the Ultra Rice technology uses relatively simple and inexpensive ingredients, the formulation incorporates the vitamin A into the starch/binder matrix, thereby protecting it from being lost during rinsing and cooking. Furthermore, when packaged under nitrogen and protected from light, the concentrate's vitamin A stability has been demonstrated at more than a year. In comparison, food products which are simply coated with a form of vitamin A can suffer significant losses from rinsing, cooking and exposure to environmental influences such as light, oxygen and moisture.

Iron fortification of Ultra Rice with a chelated, highly bioavailable form of iron has also been demonstrated. Fortification with iron, in comparison with vitamin A, in fact poses fewer technical challenges because of the inherent stability of iron compounds. However, attempts to co-fortify the synthetic rice with vitamin A and iron have not been successful. If both are combined, discoloration occurs during storage due to oxidation of vitamin A by the iron. It is possible to produce two separately produced forms of Ultra Rice – one with vitamin A and one with iron for mixing with the ordinary grains.

The Ultra Rice Process

Preparation of the vitamin A-fortified Ultra Rice final product involves three steps:

Preparation of the binder mix

One key aspect of the product is the binder mix, which gives the product its natural rice characteristics, protects the vitamin A from exposure to the environment and cross-links the rice starch to provide a stable matrix. The binder is a simple mix of several ingredients that could be mass produced and supplied as a single raw material to manufacturers of the concentrate. This approach could be attractive for several reasons: first, it protects the product patents by retaining the formula for the critical ingredient in a few hands, and second, it ensures that the materials and processing adhere to appropriate quality standards. Finally, utilization of the mix could provide estimates of quantities of rice being fortified.

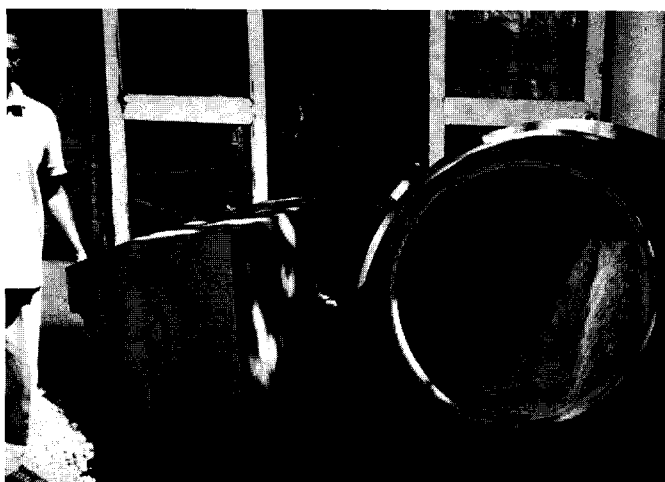
Preparation of the concentrate

The vitamin A-fortified concentrate is prepared in a multi-step process involving mixing, extrusion, cutting the extruded product into rice-shaped kernels, drying, and coating lightly with an agent to promote cross-linking of the starch on the surface of the kernel to provide a natural protective shell. The process employs common food processing unit operations and uses standard, commercially available equipment. In order to protect the vitamin A from degradation during processing, critical operations are carried out under yellow light and nitrogen blanketing. The concentrate is packed under a nitrogen blanket in moisture-proof, opaque containers.

As with any process, there are several key control parameters that affect final product quality attributes. In particular, moisture content and density must be tightly controlled to maintain both the chemical stability and organoleptic properties of the finished product.

Final blending

The concentrate must be blended with unfortified rice to provide a mix that is ready for cooking and that will contain an appropriate dosage of vitamin A. In calculating the mix ratio, allowances should be made for the small losses in potency expected during the final product's shelf life and cooking. The ratio should also factor in the approximate daily rice consumption for the target population in order to determine the vitamin A dosage



Blending can be accomplished at small rural rice mills by batch type portable mixers.

to be delivered. Blending can be accomplished by a variety of means, ranging from batch-type portable mixers that can be utilized at small rural rice mills to large continuous processes at large commercial mills. The blended product is then ready to be packaged and distributed to sale outlets.

To test the feasibility of introducing vitamin-A fortified rice to a rural rice-eating population, the Micronutrient Initiative supported PATH (Program for Appropriate Technology in Health) to implement a project in Indonesia. The innovative project was implemented from 1994-1996 and involved multiple private and public sector groups, including the private developer of the Ultra Rice technology, PATH, local Indonesian NGOs, as well as private and public Indonesian rice millers. The project addressed technical, logistical and cultural aspects of rice fortification. Major accomplishments of the project included the following:

- Verification of the stability of vitamin A in the fortified concentrate under field conditions

- Validation of a mixing procedure for medium and small rice millers
- Demonstration of consumer acceptability of the product
- Demonstration of feasibility of selling the product in various types of local outlets
- Generating national, provincial and local government interest in fortification of rice

Conclusion

This initial study demonstrated the acceptance and marketability of vitamin A-fortified rice in Indonesia. Further studies related to cooking and shelf-life stability, as well as overall efficacy in alleviating vitamin A deficiency, are to be implemented as soon as funds are available. The University of Arkansas is currently conducting an independent review of Ultra Rice, and its evaluation will provide useful information towards defining important next steps to be taken in advancing the use of this technology. Since the completion of this project in 1996, and because of PATH's interest in the technology, the inventor of Ultra Rice transferred its intellectual property rights to PATH, thereby entrusting its future to the public sector. In order to have a real impact on nutritional status, the technology must be widely available, which will require a considerable investment from various public and private organizations involved in food fortification in primary rice-consuming countries.

In order to make this important new technology widely available to those rice-consuming populations suffering from VAD, several additional activities will be required. The Micronutrient Initiative, along with other donors, will be working in collaboration with PATH in gaining the advice and support of the nutrition community for the advancement of this promising technology.

Condiments & Other Products



The Fortification of Food-Flavor Improvers

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Abstract *Fortification of condiments that improve the flavor of foods often does not fit concepts of "healthy" foods. However, these are part of human dietary tradition. It will be very difficult to replace them with healthier substances. Condiments are attractive vehicles because they are inexpensive and therefore affordable for most of the population, very stable under normal weather conditions and therefore very easy to store and to distribute. They are widely consumed by all ages and social strata and reach vulnerable populations and are consumed in constant amounts, making fortification levels relatively easy to establish. Few foods have so many practical advantages as vehicles of essential micronutrients.*

Introduction

This presentation focuses on specific aspects of the fortification programs which have contributed to their success, rather than on technological descriptions of the fortification processes. The conclusions originated from our experiences with the fortification programs in Central America that could be valid for other regions of the developing world. Some of these issues may be controversial. However, if the programs in Central America are to contribute significantly to the prevention and control of micronutrient deficiencies in other parts of the world, these issues must be critically analyzed.

Fortification of condiments and other substances that improve the flavor of our diets has had opponents, because condiments do not fit the concept of "valuable foods". Indeed, reduction of their intake is recommended in many countries because of health considerations. Thus, high intake of salt is undesirable because of its putative association with high blood pressure. Similarly, intake of sugar is discouraged to prevent the development of dental caries. However, all these products are

part of human culture, and it is very difficult to replace them with healthier and less expensive substances. Therefore, their use will continue. Why not use them as vehicles for micronutrients, while simultaneously assuring that their intake will either be reduced or at least not increase?

Most of the successful food fortification programs in the developing world are those that use these flavor improvers. For example, through salt fortified with iodine, Ecuador, Bolivia, and many other countries in the world have overcome iodine deficiency, preventing endemic social scourges such as cretinism, mutism and mental retardation. Through double fortification of salt with iodine and fluorine, Costa Rica and Jamaica have accomplished the reduction of both IDD and tooth decay nationwide. Sugar fortified with vitamin A, El Salvador, Guatemala and Honduras are significantly reducing this nutrient deficiency, improving the general health status of their populations.

The proven efficacy of fortification of these food-flavor improvers is attributable to some of their special

characteristics. They are inexpensive and hence affordable for most of the population. These foods are very stable under normal weather conditions and therefore very easy to store and to distribute. Finally, they are widely consumed in constant amounts by all ages and social strata and therefore very easily found in remote places. No other foods have so many practical advantages for being vehicles of essential micronutrients.

Misconceptions About Food-Flavor Improvers

Even though the impact of fortification of these staples has been proven, some misunderstanding remains and often creates resistance to the widespread acceptance of these successful experiences. I will refer to them as *Five Misconceptions*.

Fortification should be universal

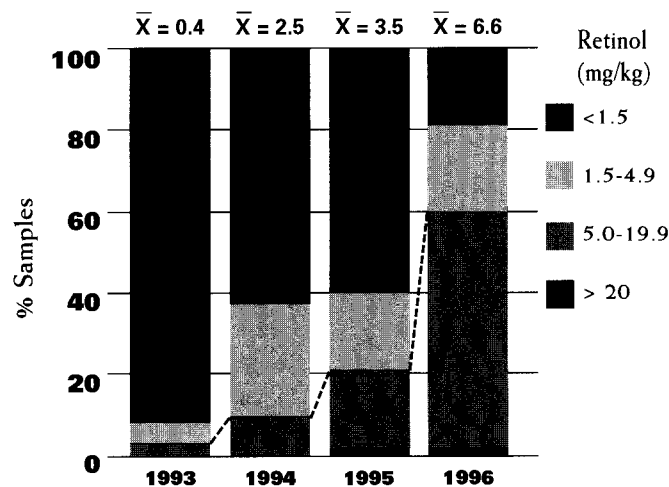
The prototype of "staple food" fortification is salt fortification with iodine. Fortification of this commodity is accepted almost everywhere, because almost all diets in the world are lacking in this nutrient. Fortification of all salt, regardless of its use, has been recommended—that is, "universal salt fortification." However, food-flavor improvers are also used in considerable amounts by food and non-food industries. For some of these the presence of the fortificant is inappropriate. In some cases the fortificant is destroyed or unnecessary for the final product. Nowadays, universal fortification programs of these commodities are under attack by such industries and importers because they see the demand for universal fortification as technical barriers to free trade. This circumstance is unnecessarily putting fortification programs at risk.

In Honduras, the government allows the production of non-fortified sugar for industrial use. In the past this constituted a problem, because there were no practical and inexpensive ways to distinguish the fortified from the nonfortified sugar, and both types of sugar were mixed at the household level. This seriously impairs the achievement of the program's nutritional goals. However, in the sugar harvest season of 1995-96 the producers adopted a special label for the fortified sugar and provided clear instructions to warehouses to distribute only the labeled product for domestic consumption. The result was good. Fortification of 40% of the national sugar production coincides with 80% of all the households having fortified sugar. There is still a 20% leakage of nonfortified sugar to homes. However, this case

demonstrates that if good labelling and distribution practices are implemented, fortification programs could succeed without being universal.

Nevertheless, it is essential to point out that this policy is applicable only where reliable labelling and enforcing mechanisms are in place, and where producers commit themselves to clearly identify and control the distribution of the fortified and the non-fortified products. It is very important to create mechanisms to assure that only the fortified product reaches consumers at the household level.

Honduras Trend of Sugar Fortification at the Household Level



The samples in the "target range" of 5-20 mg/kg increased to 60% while non-fortified samples (less than 1.5 mg/kg of retinol) dropped dramatically after the introduction of quality assurance practices by producers.

Presence of the fortificant should be confirmed everywhere.

Several international cooperative institutions have been promoting the use of a "field kit" to detect the presence of iodine in salt. The intention was good, but the final results, at least in our countries, have not been acceptable. In some situations these kits have been promoted as semi-quantitative procedures, when they were not. Thus, the "field kits" created more confusion and problems than benefit or improvement of the fortification programs. In fact, producers in Guatemala actually decided to reduce the amount of the fortified mixture used in salt iodization because they misinterpreted the "field kit" results to mean the salt was rich in iodine when it was not. It is important to point out that the

impairment of the salt fortification program was discovered thanks to a surveillance system sponsored by UNICEF. The alarm was given, and now corrections are being implemented. Our most recent information shows that 30% of salt is adequately fortified at the household level.

The Guatemalan situation regarding salt fortification is very interesting, because this country was the first one in Latin America to control iodine deficiency by this means in the 1950s. However, 40 years later the quality of the program is still unsatisfactory. Guatemala decided on universal fortification instead of the industrial development of salt production.

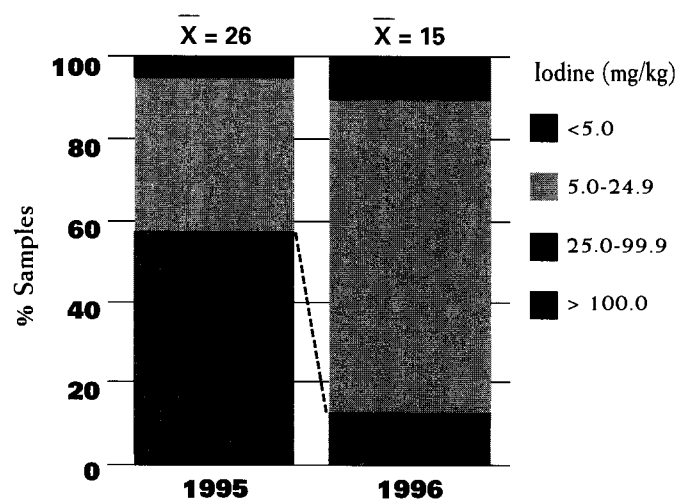
Using the same argument that quality of the fortification programs could be improved by testing the fortified products everywhere, currently there are many efforts to develop "field methods" to be used for untrained personnel and for consumers. These kits may contribute to monitoring the compliance of the fortification programs at the local level. However, the overall picture of quality assurance and monitoring is becoming unnecessarily complex and expensive. As a matter of comparison, how often and with what intensity are the fortified foods in the developed world being checked in each distribution truck and each retail store? Why, then, is such a structure being promoted for poor countries that do not have sufficient personnel or resources to do so?

We evaluated a quality control and quality assurance program in Honduras, and concluded that the key point of success is quality control at the factory level, coupled with identification of the product with a proper label and the possibility of the producers being subject to inspection. When producers cannot implement a quality control process, government should take that responsibility until it is adopted by the food industries. Monitoring practices at other stages of the marketing chain should be very simple and based more on enforcement of labelling and packing rather than on chemical analysis of samples. However, because human nature is weak, and because this characteristic is more widespread where poverty and ignorance are prevalent, we found that the presence of a surveillance system at the household level is very useful. Such surveillance may consist of an annual sampling of the fortified foods at the household level. The data from this practice not only will show the performance of the quality assurance system but also will provide an approximation of how the nutritional goals are being approached.

The level of the fortificant in food samples at the household level should be that indicated in the legislation.

Salt, sugar and similar products have very long shelf-lives, sometimes nearly a year. On the other hand, micronutrients, especially vitamins, suffer degradation when exposed to environmental factors. Therefore, it should be expected that the micronutrient content of the food would be lower at the household level than during production. This normal loss should not be considered as a failure of the program but as a factor to be considered in estimating the original content of the nutrient in

Guatemala Trend of Salt Fortification at the Household Level



After introduction of field kits for "quality control", the percent of samples in the target range of 25-99.9 mg/kg of iodine dropped significantly.

the food during production. This fact should be reflected in the regulations. The basic objective is that the fortified food should contain effective biological levels of the nutrient when it is being consumed by the population.

In Guatemala and Honduras, we have been monitoring the loss of retinol in fortified sugar between factories and homes. In general terms, homes received 50-60% of the initial content of retinol added during production. This stability is acceptable for a nutrient and a food of this type. The retinol level of sugar in homes is high enough to be nutritionally important and to keep the intervention at an acceptable cost. In my opinion, sugar fortification has been very successful in Central America,

as it is providing vitamin A at safe levels to all people who consume sugar. Indeed, recent surveys show more than 80% of homes had sugar containing retinol at concentrations high enough to make sugar the main source of this nutrient for the population.

The biological impact of this intervention has been clearly shown by the reduction in the prevalence of vitamin A deficiency in preschoolers of both countries. Among eight Latin American countries (including Costa Rica, Panama, Colombia, Dominican Republic, El Salvador and Nicaragua) Honduras and Guatemala show the worst situation in nutrition according to indicators of low weight by age and low height by age. However, their vitamin A status measured by means of low levels of plasma retinol (<20 µg/dL) places these countries in a situation similar to that found in more prosperous nations such as Colombia, Costa Rica and Panama. These anomalous lower percentages of vitamin A deficiency are attributable to the presence of fortified sugar with vitamin A in Honduras and Guatemala.

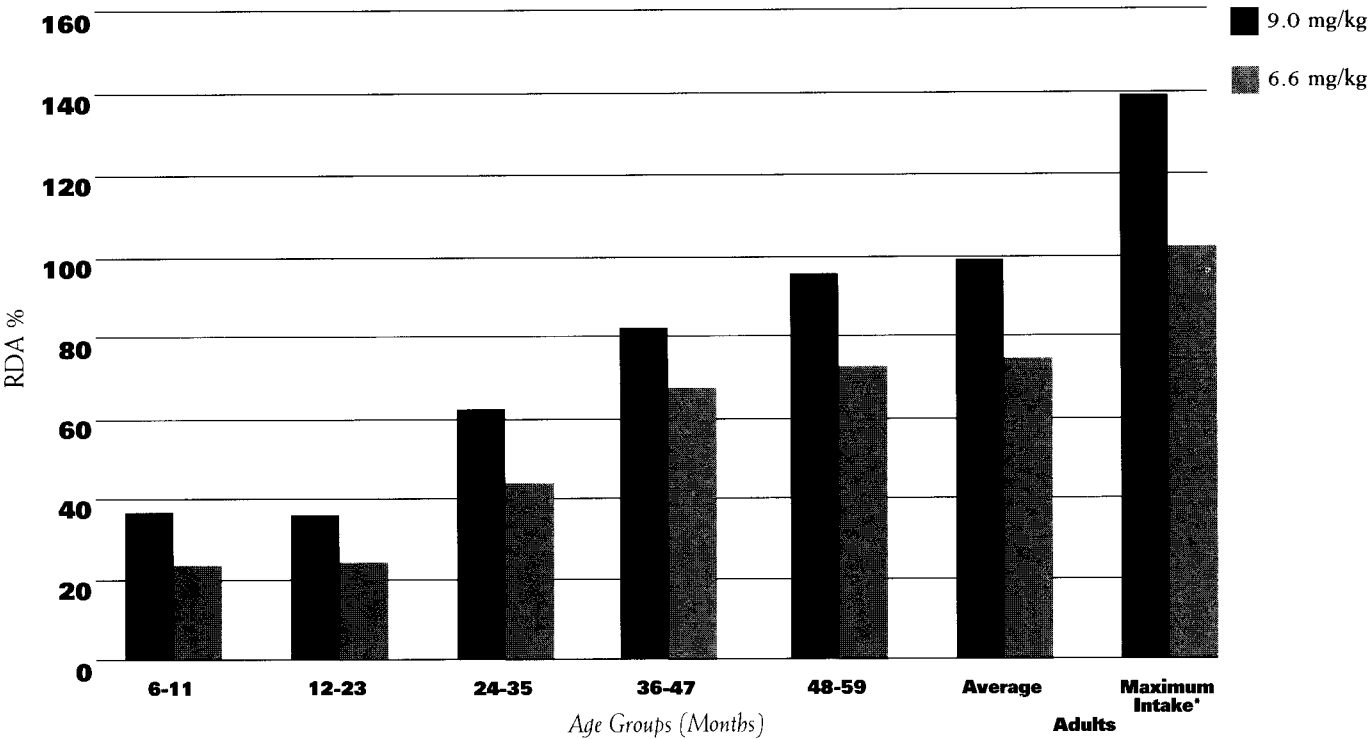
The Honduran and Guatemalan cases are still more illustrative if the plasma retinol levels are analyzed by

age. Only children from 12 to 24 months remain deficient in vitamin A. Children from 24 to 59 months are close to overcoming even moderate deficiency of this nutrient.

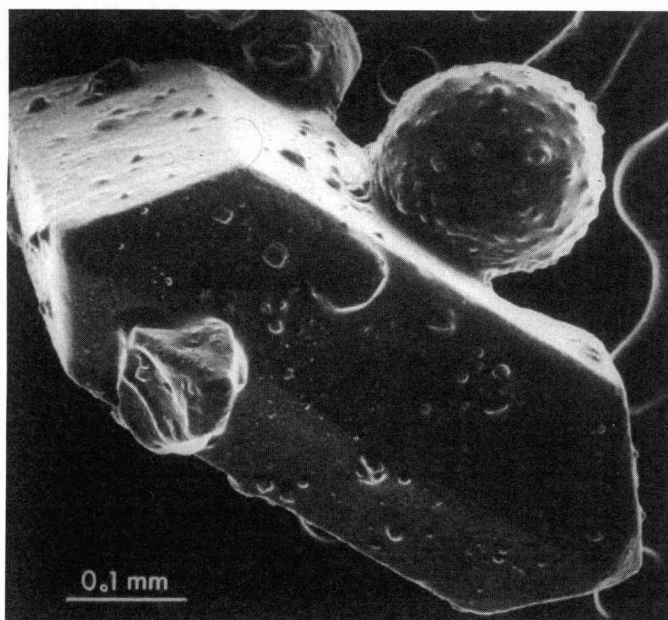
Fortification should completely correct the deficiency in those groups at higher risk.

Fortification, as well as the other interventions for preventing and correcting micronutrient deficiencies, is aimed at minimizing the occurrence of clinical and sub-clinical signs of the deficiencies, especially in the most at-risk population. For most nutritional deficiencies the most at-risk groups are infants, that is children between one and two years old. However, it is frequently overlooked that other ages could also suffer from these deficiencies. Sometimes the importance of food fortification, specifically that dealing with food-flavor improvers, is not appreciated in all its dimensions because the infants are not completely protected. However, in the case of sugar fortified with vitamin A in Central America, for example, it is valid to state that deficiency is under control for any person older than three years old. These people are

Contribution of Sugar towards RDA of Vitamin A in Guatemala.



Sugar is the main source of vitamin A for the people of Guatemala. With the exception of children below three years of age, severe vitamin A deficiency has been overcome. Children between two and three years of age will also be covered once the mean average of sugar retinol reaches 9 mg/kg or greater.



New bonding technologies efficiently adhere fortificant compounds to condiment particles, preventing segregation during production and storage. Pictured above is a beadlet of vitamin A adhering to sugar crystal.

receiving more than 50% of the RDA of this nutrient through sugar. 50% is the nutritional gap determined by means of dietary surveys. For younger children, the vitamin A intake through sugar represents about 30% of the recommended daily allowance. That makes sugar an excellent source of vitamin A, even though it has not become the only necessary source of this nutrient for this age group. Therefore, in general terms, the outcome of the program is excellent, in spite of the fact that some infants are still not receiving the daily recommended intake of this nutrient from their normal diet.

This case also shows that fortification is important in overcoming nutritional deficiencies, but it is not the only solution. Fortification must be complemented, especially for infants, by other strategies such as breast feeding promotion and use of appropriate weaning foods. In the absence of these practices it must be complemented by

periodic supplementation that provides high dosages of micronutrients by means of pharmaceutical presentations. However, with fortification, the scope and cost of all these complementary programs is greatly reduced, because fortification has already significantly narrowed the population at risk.

Fortification could provide a significant commercial benefit to the participating industries.

Commerce of food-flavor improvers in the developing world is not driven by quality but by economic gain and by consumer affordability. On the other hand, increases in the consumption of these commodities should not be promoted based on the benefits of fortification. Producers should not cash in on fortification, but rather pass the cost of fortification on to the consumers. Therefore, fortification of salt, sugar and similar products does not in principle have profit motivation to producers. Furthermore, as mentioned before, these commodities are widely consumed because of their low price. However, this characteristic is also a disadvantage for fortification, because the proportion of cost increment due to fortification is larger than with other foods. Although the increase in cost is apparently small, it is large in terms of competitiveness for the involved industries. Thus, if any developing country decides to fortify any of these commodities, this practice should be mandatory both for internally produced as well as for similar imported products. That does not mean that the industry should be obligated by the government to implement the program. The willingness of industry is still a key factor of success and sustainability of the fortification programs. The industrial sector should accept this practice and become committed to it out of conviction to its social benefits. General enforcement of the fortification programs should be seen as a motivational and protective tool for those industries that follow regulations responsibly. Fortification of staples and food ingredients are public health programs and not a means to achieve a commercial edge.

Double Fortification of Salt With Iron and Iodine

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Abstract *Recently, scientists have developed a technology to fortify salt with both iron and iodine in such a way that the two micronutrients do not interact and lose potency. This presents a significant opportunity to piggy-back iron fortification onto increasingly successful salt iodization programs. Salt production facilities have been upgraded and the marketing infrastructure for iodized salt is growing. Legislation and regulations are in place and can be adapted to iron. Salt fortified with both iron and iodine is currently being field tested in Ghana, Bangladesh and Guatemala.*

Introduction

Over the past decade there has been significant progress globally in delivering iodine through salt. More than 50% of the world now has access to iodized salt. Many countries are reaching universal iodization. More than 90 governments have provided resources for IDD elimination in their national financial budgets. The virtual elimination of an ancient scourge has become a real possibility. It has also raised the confidence needed to address other more complex micronutrient problems.

Control of iron deficiency anemia continues to lag behind. Iron supplementation programs often have low coverage and poor compliance. A few countries are beginning to plan large-scale fortification programs adding vitamin A to staple foods like oil and sugar and iron to flour. Regional initiatives that involve sugar producers and flour millers are beginning to gain momentum, however, the coverage is still extremely low.

Encouraged by the progress made in several countries in implementing successful salt iodization programs, efforts have been directed at examining the feasibility of fortifying salt with iron along with iodine. With production, surveillance and monitoring infrastructure for iodization programs already in place, such an integration and coordination would enable resource savings and

maximum efficiency. The commercial application of large-scale double fortification programs would be a major breakthrough in establishing a cost-effective delivery system for iron and iodine to cover large populations.

The objective of this presentation is to review the state-of-the-art of iodine, iron and double fortification of salt and identify further testing and development work required to enable large-scale application of double-fortified salt. The considerations include possible interaction between iron and iodine, effect on their stability and bioavailability, and technical requirements for salt quality, production/refining procedures and packaging. The incremental cost is also a factor to be reckoned with while considering implementation of the fortification program on a large scale.

Salt As A Carrier Of Nutrients

In order to eliminate iodine deficiency, several ways of supplementing iodine in the diet have been proposed. A variety of vehicles such as salt, bread, sweets, milk, sugar and water have been tried. Among these the iodization of salt has become the most commonly accepted.

Efforts to alleviate iron deficiency anemia have focused on increasing the amount of available iron in the diet through modification of food habits and fortifica-

Salt Iodization in Asia

	Pop at risk IDD (Millions)	Year of Salt Regulation	% Iodized Salt Production	% Iodized Salt Consumption
China	425	1994	85	60
India	270	1985	70	61
Indonesia	150	1986	84	58
Nepal	20	1996	87	50

tion of selected foods. Wheat flour is a common vehicle for iron fortification in the developed countries. Maize and rice have also been proposed. In these countries, the grains are processed through centralized milling operations and lend themselves readily to iron fortification. However, this is rarely feasible in less-developed countries where food is eaten where it is grown. In view of this, recent research in iron fortification has been directed to non-staple or accessory food items as vehicles for fortification. Specifically salt, sugar, curry powder and fish sauce have been considered as possible vehicles for iron fortification programs.

Salt is a suitable carrier of essential nutrients for a number of reasons. It is consumed in all regions of a country at fairly uniform levels not linked to dietary patterns. Salt is consumed by all average adults in approximately the same amounts each day constantly throughout the year. This makes it possible to determine accurately the appropriate level at which a particular nutrient is to be added and to control its intake. In several less-developed countries salt is one of the few food items that comes from outside the village. In many countries, the production of salt is centralized or is concentrated in a few locations and its distribution is regulated to some degree by the government. Therefore, the control of a salt fortification program may be economically and administratively feasible. Salt is well distributed in all food preparations, ensuring the presence of metabolites which aid in the utilization of nutrients.

The concept of salt fortification is not new. The introduction of iodine through salt has been practiced successfully in several developed countries for nearly 60 years. Over the past decade, salt iodization programs in

developing countries have been made effective with better planning, coordination, education and monitoring. Consumption of iodized or iodated salt has helped reduce considerably the prevalence of iodine deficiency disorders in many parts of the world. In the developed countries, salt for cattle is used as a carrier for trace minerals like manganese, zinc, copper, iron, cobalt and magnesium. Enriched dough salt premixes containing iron, niacin, riboflavin and thiamine hydrochloride are added to dough for bread manufacture. In certain countries salt is being used as a carrier for sodium and calcium fluorides.

Key considerations in salt fortification

1. Fortified at the source of production for administrative and economic efficiencies.
2. Fortifying agents stable for at least 6 months from time of consumer purchase.
3. Salt is often added while cooking for 30-40 minutes. Fortification process could minimize nutrient loss during this period.
4. There is often a 3-4 hour time lag from cooking to eating. The fortificant must remain stable during this post-cooking period.

Iodization Of Salt

The process of salt iodization aims to mix salt with a prefixed quantity of iodine to ensure the desired dosage of iodine in the salt. Iodine is normally introduced as potassium, calcium or sodium iodide or iodate. In the developed countries potassium iodide is used extensively

for iodization of refined table salt. It works well when the salt is extremely pure (+99.5%), dry (moisture content less than 0.1%) and is packed in air-tight and water-proof containers. The high solubility of the chemical enables dispersion using atomized sprays on very dry crystals. Sometimes it is dry-mixed with the salt.

Potassium iodide in salt can, however, be lost by chemical reaction, that is oxidation of the iodide in the presence of moisture caused by certain impurities in the salt. It can also be lost by physical means if the iodated salt packs are exposed to excessive moisture, becoming damp and resulting in the iodide migrating from the body of the salt to the fabric of the pack and out of the pack if the fabric is porous. The adverse effects on potassium iodide can be mitigated by using refined salt packed in water-resistant packaging.

In the less-developed countries, most of the people in IDD-endemic areas use unrefined salt in low quality packaging. For such salt, potassium iodate is more stable under adverse climatic conditions than iodide, only slightly soluble in water at low temperatures and therefore less prone to migrate out of the bag in which salt is packed.

Potassium iodate has been shown to be more suitable than iodide for fortifying salt because of its greater stability in warm, damp or tropical climates. However, the iodide can still be used in salt which is refined and properly packed.

The Iodization Process

The per-capita consumption of salt in different countries varies over a wide range from 3 to 20 grams per day. Overall iodine losses could range anywhere between 20 and 80%. Therefore, levels of iodization in different countries vary anywhere between 20-100 ppm iodine. Also, in a given country the fortification level may be changed over time in response to changes in average daily consumption of salt and reduction in iodine losses during distribution and storage.

The iodization process can be achieved by a variety of mixing processes. For powdered salt, a stock mixture of potassium iodide, a free flowing agent and salt can be dry mixed in a screw conveyor. A potassium iodate solution can be dripped onto salt crystals as they travel over an inclined belt conveyor. A fine atomized spray chamber can be followed by mixing in a screw conveyor. Mixing can also be accomplished in a batch-type arrangement by fitting a ribbon blender with an overhead spray.

Iron Fortification Of Salt

Iron has potential for use in more food vehicles than does iodine. However, fortification with iron is technically more difficult than with other nutrients since iron reacts with several food ingredients. While in the case of iodine the important consideration is the stability of the additive 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. Another factor to be considered is that iron salt dosages in salt are 30 to 60 times higher than iodine dosages.

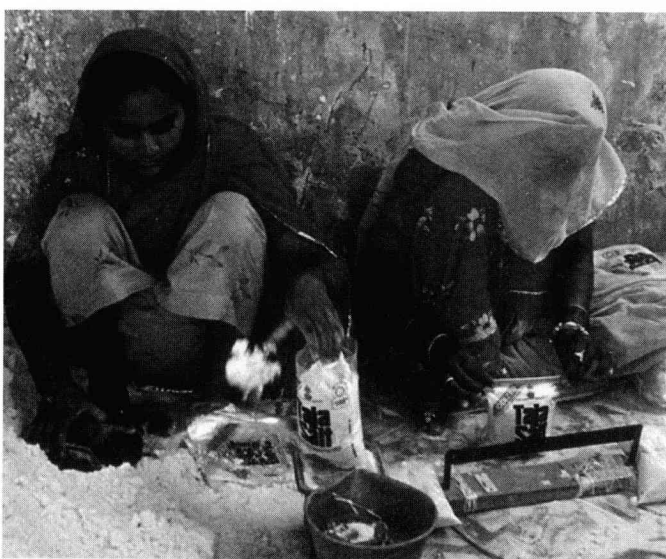
Criteria for Iron Compound

1. No discoloration during storage under varying temperature and humidity.
2. No segregation during storage under varying temperature and humidity.
3. No added flavor or odor to the salt or to food after cooking.
4. Nutritionally available after mixing and several months of storage.
5. Addition should be economically feasible.

There is no iron compound that would by itself satisfy all these requirements. The white, water-insoluble, relatively stable iron compounds like sodium iron pyrophosphate, ferric orthophosphate or ferric pyrophosphate are organoleptically inert but poorly absorbed. On the other hand, the soluble, well-absorbed iron compounds, like ferrous sulphate or ferrous citrate, discolor the salt very quickly. The solution would therefore involve increasing the absorption of ferric phosphate compounds or preventing the ferrous iron compounds from discolouring the salt.

Almost all the development work on fortification of common salt with iron has been done in India over the past 20 years. Based on Indian findings, trials have also been attempted in Thailand. The level of iron fortification recommended by the National Institute of Nutrition, Hyderabad, India is 1 gram of elemental iron per kg of fortified salt, i.e. an iron level of 1,000 ppm. On the basis of the lower level of 5% absorption of this iron and an average of 15 g of salt per day, this provides 0.75 mg of absorbed iron per person per day, which is slightly over a third of the average daily iron requirement.

Ascorbic acid, when used with ferric salts, has been known to enhance their absorption. Ascorbic acid helps reduction of trivalent iron to the divalent state, and in low pH media combines with iron to form a soluble ascorbate chelate. However, ascorbic acid is expensive and when added to salt, discolors the medium. Sodium acid sulphate has been proposed as an absorption promoter. Tests have shown that salt fortified with iron orthophosphate (3,500 parts per million (ppm)) and sodium acid sulphate (5,000 ppm) is stable for more than eight months without a decrease in iron absorption. The iron absorption from ferric phosphate nearly doubled to 80% of that obtained with ferrous sulphate. Notwith-



Consumption of iodized or iodated salt has helped reduce considerably the prevalence of iodine deficiency disorders in many parts of the world, including Asia.

standing this, iron phosphate salts are expensive, costing three to four times per unit of iron when compared to ferrous sulphate and are absorbed to a much lesser extent.

An alternative has been proposed using a coordinating agent in a low pH medium to prevent discoloration of soluble ferrous sulphate in table salt. When ferrous sulphate comes into contact with moisture in salt, the hydrolysis of the ferrous ions could be prevented or retarded by a coordinating agent that would combine with the iron compound to form a complex that is not colored and shows no tendency to polymerize. Extensive tests have shown that phosphates are effective competing ions to prevent color development. Among the

several phosphate compounds tested, sodium hexametaphosphate, with sodium acid phosphate to reduce pH, and orthophosphoric acid effectively prevented color development when ferrous sulphate was added to salt. Further studies revealed a workable formula with good bioavailability, stability on storage and acceptability using ferrous sulphate (3,200 ppm) with sodium acid phosphate or orthophosphoric acid (3,200 ppm) and sodium acid sulphate (5,000 ppm). The effect of the fortified salt on the control of anemia in children in residential schools in Hyderabad, India was studied by the National Institute of Nutrition (NIN) between 1976-79. The prevalence of anemia was reduced significantly within one year of feeding without adverse effects.

Double Fortification Of Salt With Iron And Iodine

Even though technology for iron fortification of salt was developed and field trials confirming the effectiveness of the formulation were completed in the 1970s, the program did not find large-scale application partly because it was overtaken by a major thrust in several developing countries, including India, to iodate salt to control iodine deficiency disorders. The technology and machinery required for salt iodization are relatively simple and inexpensive and stability problems are less acute. Thus, during the 1980s, salt iodization programs were formulated or are under implementation in several countries. With a systematic identification and streamlining of the bottlenecks, iodization programs have begun to show a positive impact.

Because the infrastructure for salt iodization is now in place in several developing countries, there is an opportunity to introduce iron along with iodine in salt. This also poses a challenge in developing a formulation in which iron is stable, bioavailable and does not affect the retention of the iodine. When attempts were initially made in the mid 1980s to incorporate iodine and iron in the same salt, the problem of iodine stability arose because the ferrous iron is more stable in an acidic medium, whereas the iodine salts are more stable in alkaline systems. The ferrous iron is a reducing agent that readily reacts with iodate, oxidizing to ferric iron, while reducing the iodate to free iodide.

Testing Stability

For the mutual co-existence of iron and iodine in double fortified salt, it is necessary to look for suitable stabilisers. Alternatively, stable and neutral salts of iron have to be

While in the case of iodine the important consideration is the stability of the additive 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.

identified that will be compatible with potassium iodide or iodate in a slightly alkaline medium. These approaches have been tested and workable formulations proposed in India and Canada.

Narasinga Rao (NIN), India

Narasinga Rao reported development of a formula using ferrous sulphate (1000 ppm Fe), potassium iodide (20 ppm Iodine) and a stabilizer (a chelating polyphosphate). He has reported good bioavailability and stability of the double-fortified salt under different conditions of storage. The formula proposed by Rao is:

Ferrous Sulphate 3,200 ppm
Potassium Iodide 40 ppm
Stabilizer (Sodium hexametaphosphate) 1%

In 1985-1987, NIN field-tested a formula for double-fortified salt using ferrous sulphate heptahydrate (0.5%), sodium hexametaphosphate (SHMP) (1%) and potassium iodate (70 ppm). This failed to show an impact, owing to confounding factors such as malaria and hookworm infestation. NIN has recently reported a dry-mixing technique that it claims is superior to the spray-mixing technique used earlier to mix the additives with the salt. NIN proposes to conduct multi-centric trials in India to test the impact of its DF salt, acceptability and bio-availability.

Work done by Diosady and others at the University of Toronto has shown that the NIN formula works well in pure salt but shows heavy iodine losses in the presence of magnesium chloride as an impurity in the salt. Unfortunately, hygroscopic impurities in salt allow the reaction of the iron and iodine compounds to take place. While SHMP is very effective in binding water, in the presence of significant quantities of magnesium chloride the iodine content of the salt drops rapidly.

An Indian Company, Sundar Chemicals, has also reported development of a stable double-fortified salt containing 1,000 ppm iron and 30 ppm iodine. Although the exact constituents are not reported, the company claims that the product is stable for more than one year. Efficacy trials conducted on a group of tea-estate workers in southern India showed significant improvement in hemoglobin levels compared to a control group. There was also an 18% improvement in work output.

Mannar et al., India

After tests with various iron and iodine compounds, Mannar et. al. have reported that ferrous fumarate and potassium iodide represent a workable combination without stabilizers. Ferrous fumarate, which is a poorly soluble but biologically well-absorbed iron compound, has a pH close to 7. On hydrolysis, the medium is neutral and should cause fewer organoleptic problems. While it is naturally reddish brown in color, the small concentration of 3.1 g per kg of salt (for a 1,000 ppm Fe concentration) does not impart any noticeable color to the salt and does not deteriorate with time in salt. Owing to the fine particle size (200 mesh), it can be added in a dry form as a rich mix and still get evenly dispersed in the salt. Its toxicity is less than that of ferrous sulphate and the effect on stomach lining is less than ferrous sulphate or ferrous gluconate. Potassium iodide, unlike potassium iodate, is not an oxidizing agent and will therefore not react with ferrous fumarate. Salt fortified with ferrous fumarate and potassium iodide is of a very light brownish color and does not deteriorate with time provided it is kept sealed in water-proof packing. A test report on iron and iodine levels in salt fortified according to the following formula showed no depletion after eight weeks.

Ferrous fumarate 3,200 ppm (Iron content 1,000 ppm)
Potassium iodide 65 ppm (Iodine content 50 ppm)

L.L. Diosady, University of Toronto

A physical barrier between the iron and iodine compounds would prevent these reactions from taking place. It has been determined that encapsulation of the potassium iodate in an edible matrix improves iodine retention to 73% after six months. However, if magnesium chloride is present, the samples discolored. The problem has been resolved by use of a water-insoluble encapsulating medium. Fumarate oxidation is much slower than that of sulphate. Problems of non-homogeneity were observed during dry mixing of the additives. Unfortunately, this is an inherent problem in mixing in homogeneous solids. The variability can be narrowed by controlling particle size and by two-stage mixing.

The University of Toronto recently has reported development of a stable formulation of salt, double-fortified with iodine and iron, under a study sponsored by the MI and IDRC. Micro-encapsulation has helped create a barrier between the iron and iodine compound (ferrous fumarate and potassium iodate) and retained them in their stable form under varying conditions of salt purity and packaging, temperature and humidity for periods of up to a year. In-vitro and in-vivo studies on this formulation in rats and humans have also shown good iron and iodine absorption. An efficacy trial is currently in progress in Ghana to assess the impact of consumption of the double-fortified salt on iron and iodine status in a large population. The results will be available in early 1998. This will be followed by a multicentric field trial in three countries to assess the consumer acceptability and effectiveness of the salt in improving iodine and iron status in a commercial market setting.

Processing and Economic Implications

Depending upon the type of salt and packaging currently available, implementation of a large-scale double fortification program may require streamlining of salt production/refining and packaging operations. It would involve capital investment in equipment to upgrade salt and packaging and support facilities to be borne by the salt producer. In addition, there would be a need to address the incremental cost of refining and fortification and packaging, which could increase the price of salt anywhere from 25-50%. Funding this during the initial phase of the program is a critical input and may take the form of a combination of a subsidy/marketing incentives provided by the government and a progressive price increase.

While the price increase on account of fortification as a percentage of the price of salt may appear formidable, it should be viewed in absolute terms. An average family of five in a typical developing country setting spends about \$2 to \$4 annually on salt for domestic use. A 50% increase in retail cost would increase this by up to \$2 per year. Needless to say, the benefits accruing out of continuous and sustained use of double-fortified salt will far outweigh this expenditure.

An additional consideration is that the process of improvement in salt quality and packaging is already ongoing in several countries, with a general improvement in standard of living and enhanced consumer expectations. Higher product quality has necessarily meant higher prices, which the consumer is now willing to bear. Salt iodization programs have accelerated this process over the past decade and a double fortification program may be needed to further speed it up.

Sugar Fortification With Vitamin A: A Central American Contribution to the Developing World

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Abstract *Sugar was first fortified with vitamin A in Guatemala in the mid 1970s, cutting VAD in children in half. With the political unrest and economic turmoil of the ensuing decade, fortification ceased and within a few years VAD once again assumed alarming proportions. Recently, a partnership of government, the sugar producers, INCAP/PAHO, USAID, UNICEF and others worked to reestablish conditions for fortification. The government granted producers a temporary exemption from import duties on vitamin A concentrate and new machinery. Technical assistance was offered by a number of organizations. Once again, VAD in children has been cut in half.*

Introduction

Sugar fortification with vitamin A in Central America has a long history, starting in the 1970s. The technological and economical feasibility, as well as the biological impact, was clearly proven, and its efficacy was the precipitating factor for its introduction as a national program in Costa Rica, Guatemala and Honduras. However, the programs had very short lives mostly because of economic reasons. Fortunately, the programs came back to life during the early 1990s, when the world looked at the year 2000 as the deadline to overcome many human afflictions, among them, vitamin A deficiency.

Nowadays, sugar fortification takes place as a national program in El Salvador, Guatemala and Honduras. Other countries, such as Nicaragua, Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Mexico, India, the Philippines and Zambia have plans in this regard.

During this new phase in the life of sugar fortification as a public health program, we have reviewed the original process and determined the behavior of the fortified sugar under "true life conditions". This new knowledge pertains to the stability of the retinol during sugar production, marketing, and during its use by relevant food industries.

Characteristics of Sugar Fortification Programs

Sugar fortified with vitamin A is a mixture of sugar, either standard or refined, retinyl-palmitate beadlets, vegetable oil and antioxidants. The beadlets contain, in addition to retinol, antioxidant substances and a gelatin matrix, which are there to increase the stability of vitamin A under adverse environmental and commercial conditions, and to make it water dispersable. Vegetable oil is used as the adhesive between the beadlets and the sugar crystals.

The Roche Corporation and INCAP have been carrying out experiments designed to identify other compounds that could replace vegetable oil as the adhesive element, because the oil tends to become rancid in the premix after two months of storage under tropical conditions. So far, we have confirmed that peanut oil and other vegetable oils with a lower amount of unsaturated fatty acids and a lower tendency to become rancid continue to be the best options. Once the premix is diluted into sugar, this oxidation does not have any importance.

The process of fortification consists of diluting this vitamin A premix over the sugar during the final steps of its production. The premix has a retinol concentration 1000 times larger than the expected final level in the

product. The ideal point of the premix addition is after the drying step in the turbines, because part of the vitamin A beadlets are separated from the sugar crystals due to exposure to warm-wind currents inside this apparatus. Originally, fortification was done before the drying turbines, because they act as large mixing devices. However, the disadvantage of adding the vitamin A premix after this point is that most sugar mills lack a mixing system to assure retinol homogeneity. To overcome this limitation, the Department of Food Technology of the University of Campinas in Brazil has designed a simple system that consists of two feeding chutes – one for sugar and the other for the vitamin A premix, and an endless screw that performs the blending. The system requires a minimum length to ensure sufficient mixing. Initial results are promising, and it is expected that sugar mills will be willing to introduce this additional structure into their actual system.

New Insights Into the Sugar Fortification Process

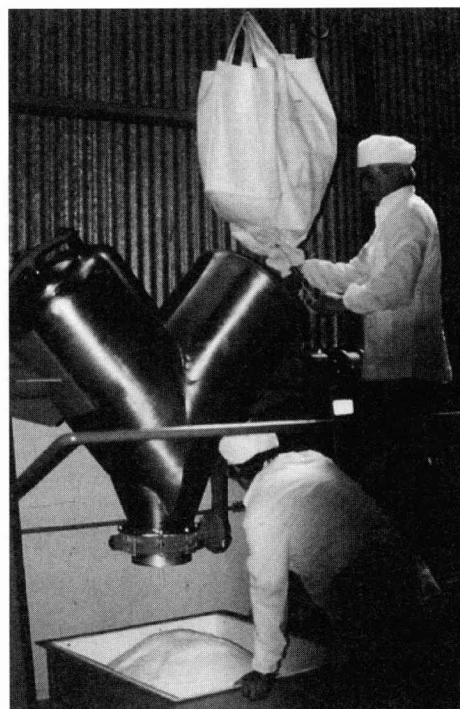
During the last two years, a quality assurance system for the complete program has been introduced in Guatemala and Honduras, in the latter country with support from the International Life Science Institute (ILSI). It consists of a quality control component carried out by producers; monitoring at factories, warehouses and retail stores by governmental personnel; and surveillance of the final product at the household level. This simple quality assurance system has provided us with a great deal of interesting and useful data, on which most of the following information is based.

Efficiency of the fortification process at factories

Mass balance analysis of the retinol content from the premix and its final product, the fortified sugar, has revealed that the process has an efficiency between 70 and 85% when the fortification takes place before the drying turbines. That means that the theoretical 1:1000 dilution of the premix over the sugar should be reduced to 1:700 to 1:850, according to the particular situation of each sugar mill. These data strengthen the need to apply the premix after the drying turbines. However, the actual system is still valid because of its clear usefulness and biological impact.

Stability of retinol in sugar through the marketing chain

Sugar samples have been obtained from households, using nationally representative survey samples, both in



In Guatemala, a small facility centrally produces premix for all the nation's sugar processors.

Guatemala and in Honduras. Sampling has taken place five to six months after the end of one sugar cane harvest season and two to three months before the next one. Therefore, the data are fairly representative of the average values that could be obtained during the year.

In 1996 the mean content of retinol in sugar at homes was 6.9 mg/kg in Guatemala, and 6.6 mg/kg in Honduras. In Honduras, this value is confounded by the leaking of non-fortified sugar into the households, which adds up to 20% of the sugar available in the market for human consumption. If that portion of sugar is eliminated from the calculation, the average is increased to 8.0 mg/kg. Those results suggest that in Guatemala, 63% of the initial retinol in sugar reaches homes, whereas in Honduras this value is 51%.

It is important to point out that for the 1995-96 harvest of sugar cane, 98% of Guatemalan households and 82% of Honduran households had sugar fortified with vitamin A at the moment of the surveys; and that in 75% and 66% of the samples the retinol content was above 5 mg/kg, respectively. We are proposing that four to six months after the conclusion of the sugar harvest, 100% of the households should have fortified sugar and 80% of

these should have sugar with retinol levels above 5 mg/kg. These criteria assure that the mean retinol content in sugar would be at least 9 mg/kg during the year. This retinol level would provide nearly 100% of the RDA for most persons from sugar alone, completely fulfilling the nutritional goal of providing 50% of the RDA for most populations; only children younger than two years old would be receiving less than this amount.

Under the actual circumstances, it is valid to say that severe vitamin A deficiency has been overcome in Guatemala and in Honduras, with the exception of children below three years of age, whose sugar intake is naturally low. Children between two and three years of age will also be covered once the mean average of sugar retinol reaches 9 mg/kg or greater. The results from recent national surveys demonstrate the biological impact of this intervention. The percentage of preschoolers with low levels of plasma retinol ($< 20 \mu\text{g/dL}$) reduced from 40% to 13% in Honduras, and from 27% to 15% in Guatemala. Comparatively, similar surveys in the neighboring countries of El Salvador and Nicaragua revealed that the situation is a public health problem in the absence of sugar fortification and other interventions.

Stability of retinol when sugar is used as an ingredient

Currently, the soft-drink industry is the main consumer of sugar in Central America; 15 to 25% of the total national consumption is devoted to this use. Other

important sugar consumers are candy factories and bakeries, which represent an additional 10% of the sugar consumption at the national level. Our recent studies revealed that retinol from sugar is very stable in the two latter industries, in which 70 to 90% of the added retinol is maintained, and it remains in considerable amounts during the entire shelf-life of the products.

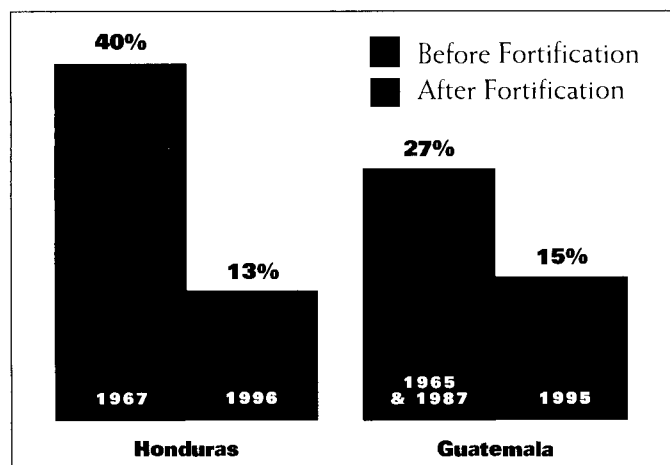
The situation with the soft drink industry is different. If standard sugar is used, retinol is completely destroyed because of the clarification (or whitening) process of the sugar syrup with active charcoal and diatomaceous earth. In the case of refined sugar, the procedure of whitening is avoided, and 33% of the retinol from sugar is destroyed during soft-drink production. Retinol content in drinks made in this manner decreases a further 30% during the first week of storage. Further losses occur very slowly after this period, the reason why soft drinks in Guatemala made with refined and fortified sugar contain some retinol (25% RDA for adults). These results suggest that if it were possible to separate sugar destined for the soft drink industries, that type of sugar might not be fortified.

Use of nonfortified sugar for the candy and bakery industries is a matter of internal decision of each country. Retinol remains in these products, and its presence does not mean any health risks to consumers. Indeed, retinol intake, through all sources in which fortified sugar is an ingredient, is much lower than the level recommended as safe (3.3 mg/day) for pregnant women, whose child-to-be may suffer due to high dosages of retinol. Nevertheless, countries with universal programs of fortified sugar with retinol should consider abstaining from adding retinol to other foods above restitution levels.

Cost-Effectiveness Analysis

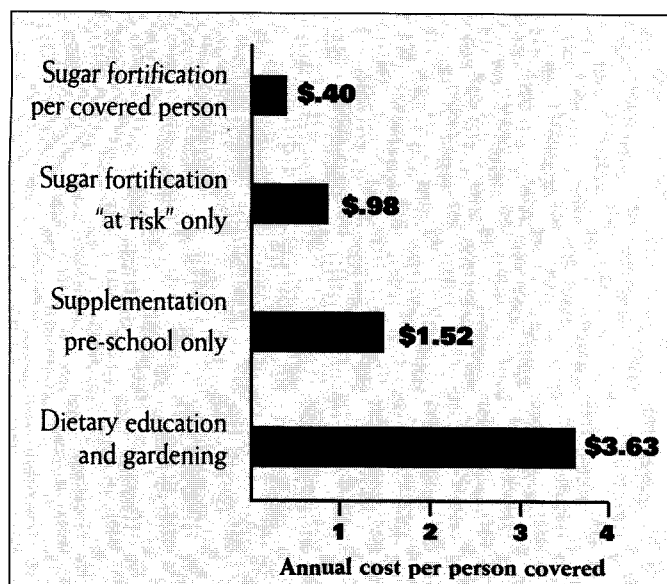
In 1991 the Project of Latin America and Caribbean Health and Nutrition Sustainability, supported by USAID, made a cost-effectiveness evaluation of three interventions to prevent and correct vitamin A deficiency. These interventions were sugar fortification, supplementation with pharmaceutical dosages of vitamin A and promotion of vegetable production and consumption. The study concluded that sugar fortification was the strategy with the larger coverage and the best cost efficacy: US\$0.98 per year per at-risk person (cost per person is US\$0.40), US\$1.52 for supplementation that covers only pre-school age children, and US\$3.63 for vegetable consumption.

Preschoolers With Low Plasma Retinol



Recent national surveys demonstrate the biological impact of sugar fortification with vitamin A. The prevalence of preschool aged children with $<20\mu\text{g/dl}$ was cut dramatically in both Honduras and Guatemala.

Intervention



A 1991 study in Guatemala comparing interventions to correct VAD concluded that sugar fortification provided the largest coverage and best cost efficiency.

Using all the information that we have now, we can re-estimate the cost of the sugar program. It is US \$3,654,000 to fortify 350,000 M.T. of sugar. From this amount 95% corresponds to the cost of the fortificant. One must add the cost for monitoring and program evaluation, which represents an additional expenditure of US\$60,000 to US\$100,000 per year. Consequently,

the yearly cost per person at risk who is recovered from deficiency is US\$1.01 for the total program. This figure shows that sugar fortification continues being the most cost-effective intervention in Guatemala, even if the fortification is universal. Thirty percent savings might be obtained if production of non-fortified sugar for industrial use were allowed. However, the risk of losing control of the program might seriously affect the value of introducing this strategy. Therefore, it should not be implemented until the program is very stable.

Conclusion

Sugar fortification in Central America has been an effective and efficient intervention to overcome and to prevent vitamin A deficiency. In spite of the identified limitations, such as non-homogeneous final product, and 40 to 50% retinol losses during the shelf-life of the product (eight months), it continues being a good strategy, with favorable cost-effectiveness and coverage. Therefore, in its actual state it is valid to consider its introduction in other countries that are affected by this deficiency. However, this program should continue being a matter for research, to make it more efficient. Areas of investigation include searching for systems to add and to blend the fortificant mixture with sugar at the factories, and developing a retinol beadlet or similar compounds that might prove more stable under adverse environmental conditions. In essence, however, the program works as it currently exists.

Fortification of Corn Starch in Latin America

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Abstract Throughout Latin America, corn starch is mixed into beverages and porridges for children and adults in medium and low-income households. Corn starch mixed with milk and sugar, the traditional "atole" drink, satisfies the need for energy, but an improvement in the nutritional profile is obtained by adding vitamins and minerals. It may satisfy hunger but it contains few essential vitamins and minerals. In Latin America today, 8 billion servings a year of fortified corn starch offer 25% of the RDA for vitamin A and iron. Based on the manufacturer's experience, incremental expenses for purchases of fortificant, additional packaging and equipment total 1% of manufacturing costs.

Introduction

In Latin America the total market for corn starch is relatively stable at about 90,000 tons a year. Of this, about 75% is used as popular fillers. That is, the corn starch is used in the home to prepare various indigenous beverages and porridges. The remaining 25% is used as an industrial culinary aid—to thicken soups and sauces, to mix with wheat flour for baking purposes, and for a host of other commercial applications.

This paper will focus only on the popular beverages and porridges that have many names in many different countries. In Mexico and Central America, the *atole* or *atol* is a somewhat thick beverage prepared with corn starch and milk and always consumed hot. In Colombia and Ecuador, *colada* is a thinner beverage that can be consumed hot or cold. In Brazil, *Mingau* is a thick porridge eaten with a spoon. In Venezuela, rice flour is commonly used instead of corn starch, to prepare *Chicha*, which is similar in consistency to *colada*, consumed hot or cold. Usually rice flour and milk are mixed in a blender. In Peru, potato starch is the ingredient of choice to prepare *Mazamorra*, which is a pudding-like popular filler. Fifteen thousand tons of rice flour a year are used in *chicha* and about 2,000 a year in *Mazamorra*.

The various porridges and beverages containing corn starch are consumed throughout the day. Children drink them for breakfast before going to school. They are con-

sumed as a snack between meals and at night as part of a light dinner. The addition of fruits and vegetables to corn starch is quite common. All told, throughout Latin America approximately 8 billion servings are prepared every year, mainly in medium and low socio-economic strata.

Quite often we hear that calories derived from corn starch are "empty calories," meaning that no other nutrient is ingested from these substances. However, one has to consider that starches are not eaten in isolation. For example, in the case of corn starch-based beverages like *atole*, the corn starch, milk and sugar used are in the exact proportion recommended by the American Dietetic Association nutritional guidelines in the United States: 60% of calories derived from carbohydrates, 30% from fat and 10% from protein. This shows the extraordinary nutritional intuition of the Aztecs, who first started mixing *atole* beverages more than a thousand years ago!

A Strategy to Overcome Micronutrient Deficiencies

Some believe that the etiology of endemic micronutrient deficiencies that affects the underprivileged populations in developing countries can be attributed to the lack of nutritional knowledge. Although they may be available, people often do not eat sufficient natural sources of iron, iodine, vitamin A and B complex vitamins. However,

from another vantage point, the diet of populations can be viewed as deficient in micronutrients for a host of economic, social or cultural reasons. I think this second point of view is more realistic. If one believes that this complex matrix of social, cultural and economic conditions is responsible for the majority of cases of micronutrient malnutrition, then the addition of micronutrients to basic foods is essential to guarantee that populations acquire the minimum amount of micronutrients needed to preserve their health and achieve their full potential. The main nutritional deficiencies in Latin America are total calories, vitamin A, iodine and iron.

As a company that literally reaches millions of people every day with a basic food like corn starch, Best-foods Latin America feels it has a moral responsibility to contribute to the health and well being of these people through the addition of micronutrients. Consequently, we fortify this product and others. Moreover, from a marketing perspective, fortification is one of the obvious steps in the sequencing ladder for our corn starch product which begins with plain starch, evolves to a flavored product, and then to a flavored and fortified version.

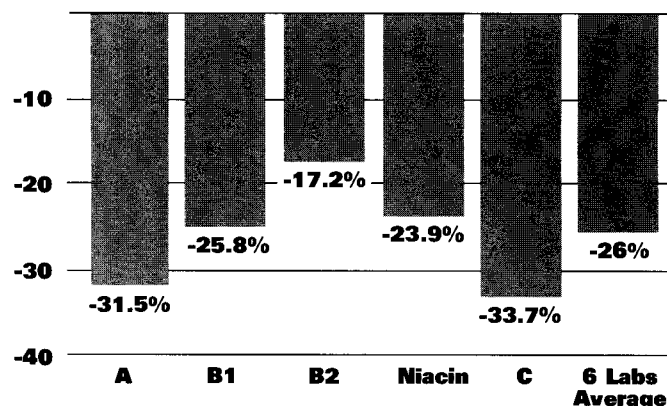
As a general rule, we recommend fortification to 25% of the daily requirements, depending on serving sizes, different recipes using corn starch and regional differences. We arrive at this level by balancing two criteria. First, we want to avoid making the consumer too dependent on one product for nutrition. Second, we want to ensure that our product contributes a significant amount of vitamins and minerals to the daily food intake.

In each country, data on the nutritional status of populations is available from official government sources, with differing degrees of thoroughness and statistical significance. We determine the exact composition of vitamin and mineral premix required using our own knowledge of consumer habits, official data on nutrition deficiencies in populations and our analysis of degradation—loss during storage, handling and preparation..

Fortificants and Premixes

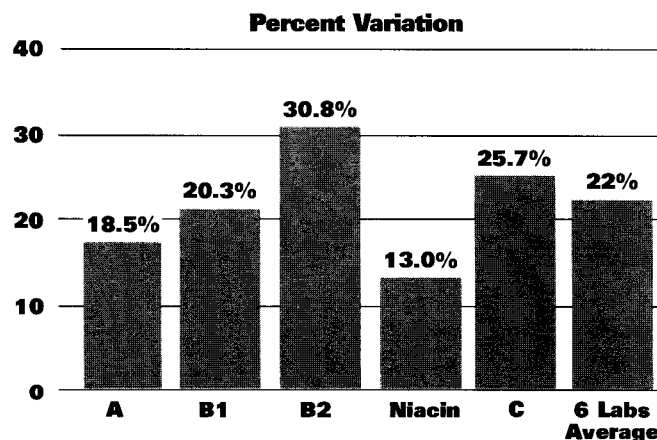
While we can determine our requirements exactly, we have found analysis to be a big problem. For example, when we compared the content of the same premix analyzed by six different laboratories in Brazil and the US, we identified two issues. First, vitamin content generally is below the expected level by an average of 26%. Second, the coefficient of variation between laboratories is

Deficits in Expected Levels of Vitamins



Results from six laboratories in Brazil and U.S. yielded results below the expected level for a range of vitamins found in samples of commercial premix.

Variation Among Laboratories



Six laboratories produced a range of results in the vitamin analysis in samples taken from a single batch of premix. Values for vitamin A content ranged from 204.2 ugRE/g to 361.2ugRE/g.

around 22%. Both values are too high and show that it is very difficult to know exactly how much of the added nutrients are being received by the populations.

In most cases, the forms of fortificant used are fairly straightforward. Iodine, in most cases, is present in the salt we use. Vitamin A palmitate is a cost-effective, stable and bioavailable form. Thiamine hydrochloride and mononitrate are suitable vitamin B₁ forms. We are using



...the public health implication of providing 25% of RDI per serving of vitamin A, iron and iodine in a widely consumed and inexpensive food product is enormous.

corn starch is then added to the final product via a Nauta mixer or a ribbon blender. Salt is usually analyzed to determine the homogeneity of the mixture and adequate dispersion and integration of the vitamins.

Based on our experiences in several countries in Latin America with a variety of corn starch-based products and premixes, the additional cost of significant levels of iron, iodine, vitamins A and B₁ are negligible. In some cases, a relatively low investment in plant equipment needs to be considered. It normally comes to less than 1% of total plant cost. Plant cost is defined as the sum of the cost of raw material, packaging material and manufacturing expenses.

reduced iron, ferrous sulfate, ferric orthophosphate, ferrous fumarate and ferric phosphate. However, there remains a good deal of controversy as to the best iron fortificant. From the food technology perspective there are a lot of questions remaining about the most bioavailable, cost-effective and stable source. There are questions about interactions with other fortificants as well as compounds in the food vehicle itself. These are questions which must be resolved in order to maximize the effectiveness of efforts to eliminate iron deficiency anemia through the fortification of food products.

Technology of Fortifying Corn Starch

As vitamin and mineral premixes purchased from various suppliers are used in minute concentrations, they are generally added in two steps. The first step is to blend a small amount of premix with a small amount of corn starch in a small mixer. This may be a ribbon blender, a flo-bin or a V-mixer. This initial blend of premix and

Public Health Impact

Given what we know about micronutrient deficiencies in Latin America, the public health implication of providing 25% of RDI per serving of vitamin A, iron and iodine in a widely consumed and inexpensive food product is enormous. We perform on-the-spot and short duration tests with small populations. A recent study on IDA at a municipal day care unit in Brazil substituted the enriched corn starch porridge for bread during morning and afternoon snacks. In a group of 34 children averaging two years and two months, the incidence of anemia dropped from 81% to 31% after two months. However, we are a responsible food producer and not in the business of public health surveillance. While we regard it as our responsibility to provide foods that can ameliorate the nutrition status of our consumers, we feel that definitive large scale and long-term public health studies on the impact of fortified products are the responsibility of governments and public institutions.

Fish Sauce Fortification in Thailand

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Abstract *In Thailand the consumption of fish sauce is widespread, averaging 20ml per capita, making fish sauce an ideal vehicle for food fortification. Although salt is the primary food vehicle to eliminate IDD, fish sauce fortification has emerged as a supportive approach and a number of producers have launched the product. Thai Ministry of Public Health is exploring double fortification of fish sauce with iron as well as iodine. Initial research indicates certain iron compounds added to fish sauce along with iodine will not change the color or taste of fish sauce.*

Introduction

In Thailand, as in other countries in South East Asia, there are many kinds of cooking condiments for improving the taste of food. Fish sauce is a traditional cooking condiment that has been used for many years throughout all socio-economic classes. Fish sauce is grouped in three categories, according to the way it is produced:

Authentic fish sauce is fish sauce that is produced by mixing a special kind of sea fish called "anchovy fish" with salt.

Semiauthentic fish sauce is authentic fish sauce mixed with salt brine and sometimes flavoring agents.

Flavored fish sauce is salt brine mixed with a small amount of the extract of authentic fish sauce and with flavoring agents such as residues from the production of monosodium glutamate (MSG), acetic acid and caramel.

The average price of each kind of fish sauce (750 ml bottle) in retail shops is as follows:

Authentic fish sauce: 25 baht (Thai baht) (75 cents)

Semiauthentic fish sauce: 10 baht (30 cents)

Flavored fish sauce: 4 baht (14 cents)

It is estimated that in Thailand, people consume 20 ml of fish sauce per person per day. Total production is more than 400 million liters/year, at a cost of around 4,000 million bahts.

The biggest market share belongs to authentic fish sauce, with 50% of the market and 2,000 million bahts, followed by semiauthentic sauce and flavored fish sauce with 1,000 million bahts each. Production quantity of authentic, semiauthentic, and flavored fish sauce is estimated at 94 million liters, 94 million liters, and 250 million liters, respectively. Flavored fish sauce has always been consumed in large amounts, since it is very cheap and affordable among people in remote areas.

Production of Fish Sauce

Authentic fish sauce contains approximately 4-108 mg/100 ml of iodine, while semiauthentic and flavored fish sauce contain no iodine.

The production process of fish sauce begins by mixing salt and sea fish together in the proportion one to three, with no water added. Some liquid emerges gradually from the mixture itself. The mixture is put into a cement tank, covered to protect it from sunlight and rain, and left for 12 months. After this time, the fish has become liquified, leaving mash and liquid, called first extract of fish sauce.

The mash is fermented again by mixing with salt brine and left for two to three months. The remaining liquid is called second extract of fish sauce. The leftover mash is again mixed with salt brine and left for two to three months, leaving a liquid called third extract of fish sauce and residue. This residue is sent to the animal feed factory.

First, second and third extract fish sauces are stored and exposed to sunlight to make them "mature" for one week. Then each kind of extract is blended in different proportions. Authentic fish sauce contains a large amount of first extract, mixed with a very small amount of second and third extract. Semiauthentic fish sauce is composed mainly of second and third extracts. Flavored fish sauce contains a small amount of those extracts, but the main ingredients are salt brine and flavoring agents such as MSG, acetic acid, etc.

After blending, each kind of fish sauce is sent for laboratory testing and then filtering, refining and filtering again before being bottled as the finished product. There are approximately 300 fish sauce factories in Thailand, half of which produce all three kinds of fish sauce. Some produce mainly authentic and semiauthentic sauces and sell the extract to small factories to produce flavored fish sauce.

The composition of fish sauce is shown in the table below.

The Composition of Fish Sauce

	Authentic F.S.	Semiauthentic F.S.	Flavored F.S.
Lysine (mg/L)	11,200.0	1,240.0	0.0
Glutamic acid (mg/L)	3,590.0	4,800.0	3,816.0
Vitamin B ₁₂ (microgram%)	0.87-3.35	0.20-1.76	na
Fe (mg%)	0.60	0.20	na
I (mg%)	4-108	0.0	0.0

Since the Food Act revision in 1989, FDA Thailand has controlled the quality of authentic and semiauthentic fish sauces, since they are considered "the controlled food."

Only a few research studies concerning fish sauce have been conducted in the past 20 years. The Department of Medical Science conducted a study four to five years ago concerning the stability of iodine added to fish sauce in the laboratory. Over a six-month period, iodine levels decreased from 8 mg/l to between 2.7-5.1 mg/l at room temperature.



Fish sauce is a traditional cooking condiment that has been used in Thailand for many years within all socio-economic classes.

The Nutrition Division collected samples of iodized semiauthentic fish sauce from factories where they were produced to determine the stability of fish sauce. The level of iodine decreased over time, and after six months the samples had lost between 34% and 55% of their iodine.

Stability of Iodine in Fish Sauce

Iodized Semiauthentic F.S. 4 samples (Factory Collected)

Sample	Iodine contents (mg/L)		
	1 month	6 month	% Loss
1	5.00	3.30	34
2	4.20	3.00	24
3	0.33	0.20	30
4	0.36	0.16	55

In the last study, conducted by Professor Romsai Suwannik of Mahidol University, 10 gm Fe + 3 Na EDTA, 0.5 gm KIO₃, and 10 drops C H₃COOH were added to 750 ml semiauthentic fish sauce in the laboratory. This mixture became concentrated iodized semiauthentic fish sauce. Of this mixture, 5 ml was added to each 750 ml bottle of fish sauce, which became iodized semiauthentic fish sauce, which could be used for cooking at the household level.



At room temperature, the level of iodine in semiauthentic fish sauce decreased over time, and after six months the samples had lost between 34% and 55% of their iodine.

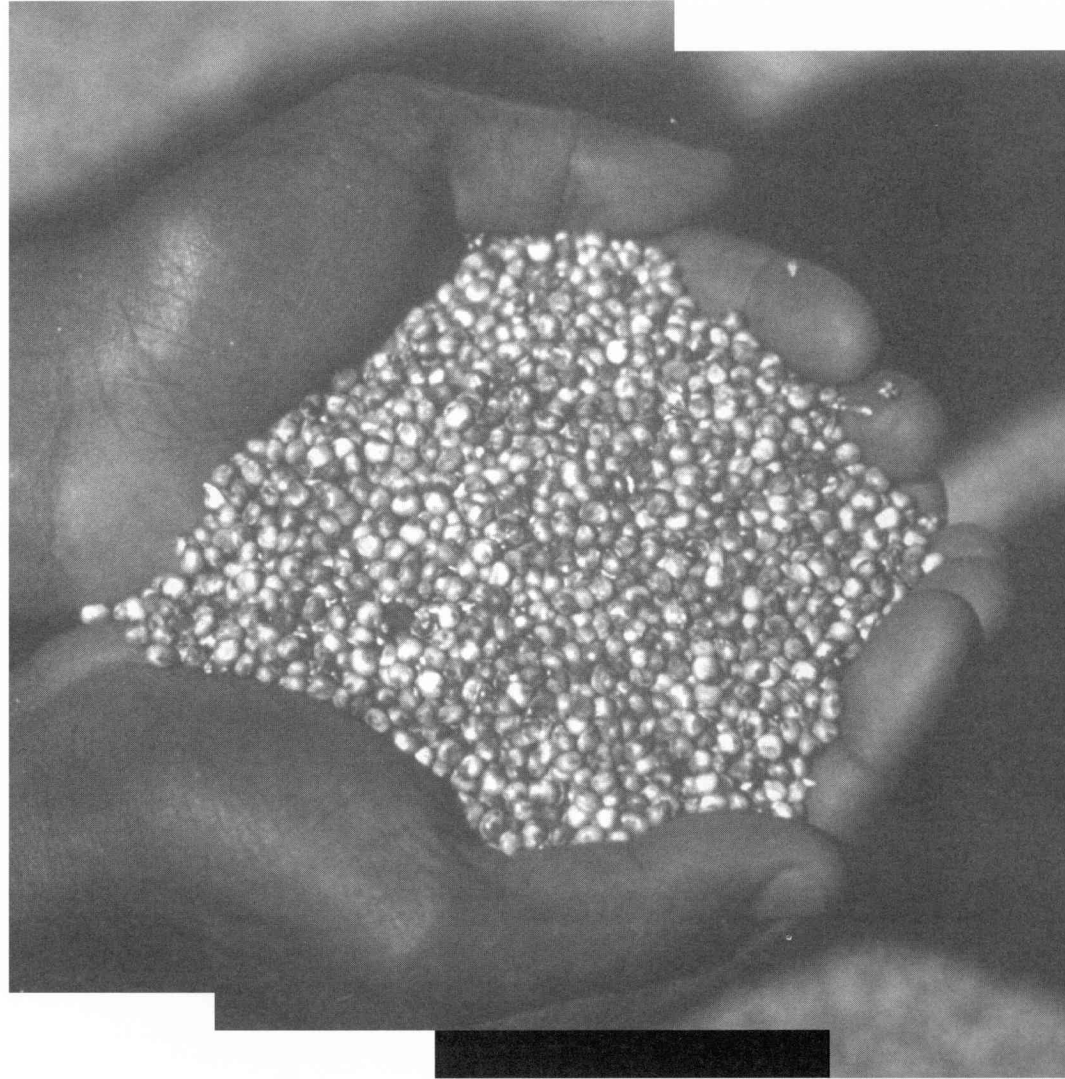
Conclusion

Fortification of fish sauce in Thailand is only in the beginning stages, since for 30 years more attention was placed on iodization of salt. Now we have convinced three small fish sauce factories in Surin, the northeast province, to produce fortified semiauthentic fish sauce. Their products are locally distributed within the nearby provinces. Before starting the fortification project in these three factories, we conducted stability studies specific to local recipes.

More research needs to be done concerning the technical feasibility of implementing fortification in each kind of fish sauce or even each recipe used in different levels of factories.

We conclude that fish sauce is a potential source for fortification because it is very popular and widely used. A challenge is presented by the large number of small producers that could be very difficult to convince about the benefits of fortification and difficult to control as far as quality assurance. More data are needed if legislation is to be the next step.

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Helen Keller International (HKI)

HKI, a US based NGO founded in 1915, provides technical assistance to strengthen existing vitamin A activities and expand vitamin A programs. The services provided include the development of educational and training materials and the dissemination of current literature and information on vitamin A.

International Life Sciences Institute (ILSI)

The International Life Sciences Institute (ILSI) is a nonprofit, worldwide foundation established in 1978 to advance the understanding of scientific issues relating to nutrition, food safety, toxicology, and the environment. By bringing together scientists from academia, government, industry, and the public sector, ILSI seeks a balanced approach to solving problems with broad implications for the well being of the general public. ILSI is affiliated with the World Health Organization as a nongovernmental organization and has specialized consultative status with the Food and Agriculture Organization of the United Nations. ILSI is headquartered in Washington, D.C. and has branches in several countries worldwide including a focal point in China.

Micronutrient Initiative (MI)

MI was established in 1992 as an international secretariat within the International Development Research Centre (IDRC) in Canada by its principal sponsors: the Canadian International Development Agency (CIDA), IDRC, the United Nations Children's Fund (UNICEF), the United Nations Development Programme (UNDP), and the World Bank. MI's mission is to help achieve the goals of the World Summit for Children that relate to the alleviation or elimination of micronutrient deficiencies. It focuses on advocacy, building alliances, the development and transfer of technology, support for national and regional initiatives, capacity building, and the resolution of key operational issues."

Opportunities for Micronutrient Interventions (OMNI)

Developed and funded by the Office of Health and Nutrition of the US Agency for International Development in Washington, DC, the OMNI project is a comprehensive 5 year (1993-1998) effort to control and prevent micronutrient deficiencies in developing countries. Participating countries will be selected based on their micronutrient malnutrition problems, the commitment by local officials (public and private) to micronutrient activities, and their capacity to achieve and sustain a demonstrable impact.

Program Against Micronutrient Malnutrition (PAMM)

PAMM is an international collaborative effort working toward the elimination of iodine, vitamin A, and iron deficiencies by the year 2000. PAMM assists governments to develop the technical capability and management systems to achieve sustained elimination of micronutrient deficiencies by holding workshops and offering technical support and training in skills needed to implement control measures. Training is an important component of PAMM's program.

Hoffmann LaRoche

The Roche Group is one of the world's leading research-based healthcare groups active in the discovery, development and manufacture of pharmaceuticals and diagnostic systems. The Group is also one of the world's largest producers of vitamins and carotenoids and of fragrances and flavours. The majority interests in Genentech, one of the world's leading firms in biotechnology, and in DePuy, a leading manufacturer of orthopaedic products, strengthen Roche's position in the healthcare market. The activities of the Group in the areas of pharmaceuticals, diagnostics, vitamins and fine chemicals, fragrances and flavours and orthopaedics focus on the prevention, diagnosis, monitoring and treatment of diseases and on the promotion of general well-being.

Founded in Basel, Switzerland in 1896, Roche is active in over 100 countries and employs about 70,000 people.

United States Agency for International Development (USAID)

Since the 1960's, USAID has played a major role in supporting research and programming to develop a sound scientific foundation for action and implementing mechanisms for international coordination, consensus building, and information sharing. To improve the prospects for child survival in the developing world, USAID has focused efforts on breastfeeding promotion, improved infant and child feeding practices, vitamin A supplementation and other interventions to address major micronutrient deficiencies as well as supplementary feeding of mothers and children. To fight micronutrient deficiencies, USAID has supported IVACG beginning in 1975; INACG beginning in 1977, Centre for Epidemiology and Preventative Ophthalmology at Johns Hopkins University, the VITAL project (1989-94); and the OMNI Project.

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