

Rice Fortification in Developing Countries: A Critical Review of the Technical and Economic Feasibility



April 2008



USAID
FROM THE AMERICAN PEOPLE



AED
Academy for Educational Development

IFT
Institute of Food Technologists
THE Society for Food Science & Technology

**Rice Fortification in Developing Countries:
A Critical Review of the Technical and Economic Feasibility**

Edited by

Sajid Alavi, Ph.D.
Kansas State University
Manhattan, Kansas

Betty Bugusu, Ph.D.
Institute of Food Technologists
Washington, DC.

Gail Cramer, Ph.D.
Louisiana State University
Baton Rouge, Louisiana

Omar Dary, Ph.D.
Academy for Educational Development
Washington, DC.

Tung-Ching Lee, Ph.D.
Rutgers, The State University of New Jersey
New Brunswick, New Jersey

Luann Martin, MA
Academy for Educational Development
Washington, DC.

Jennifer McEntire, Ph.D.
Institute of Food Technologists
Washington, DC.

Eric Wailes, Ph.D.
University of Arkansas
Fayetteville, Arkansas

This publication is made possible by the generous support of the American people through the United States Agency for International Development (USAID) under the terms of Cooperative Agreement No. GHS-A-00-05-00012-00. The contents are the responsibility of the Academy for Educational Development and do not necessarily reflect the views of USAID or the United States Government.

A2Z Project
Academy for Educational Development
1825 Connecticut Avenue, NW
Washington, DC 20009

A2Z_info@aed.org

www.a2zproject.org

April 2008

ACKNOWLEDGMENTS

The two teams that conducted the country visits are deeply grateful to the local collaborators who facilitated the visits to various companies, government agencies, and other stakeholders, and to the individuals who shared information and their perspectives on food fortification during interviews with the teams.

In China, the team was received by Ying Ching, DSM; Professor Jian Huang, Professor Chunming Chen, Professor Junsheng Huo, Chinese Centers for Disease Control and Prevention (CDC); and Professor Z. Jin, Southern Yangtze University. Professor Rui Yuan Wang, Mr. Wenling Bai, Ms. Danpi Song of the China National Cereal and Oils Association (CCOA) and China National Association of Grain Sector; Ms. Suru Li and Mr. Jun Feng of the China National Cereals, Oils and Foodstuffs Corporate (COFCO) and Food Sales Distribution Co., Ltd; Dr. Ted Greiner, PATH, and Mr. Bruno Kistner, DSM/Buhler also provided valuable information.

In the Philippines, Dr. Cora Barba, Resident Advisor for the A2Z program, organized the visits. Those interviewed included: Joshua Ramos, Deputy Director of the Bureau of Foods and Drugs of the Department of Health; Hector Maglalang, Food Fortification Consultant, and Anton Sayo, Public-Private Sector Consultant for A2Z; Ludivico Jarina, Deputy Director and Arlene Tanseco of the National Food Authority; Dr. Alicia O. Lustre of the Food Development Center of the National Food Authority; Mario Capanzana, Director, Food and Nutrition Research Institute (FNRI); and Dr. Gerald Barry of the International Rice Research Institute (IRRI); Mr. Patrick Hsu, Superlative Foods; Mr. Joey and Ms. Cristina Go, CLG Foods.

In Costa Rica, the team met with Marianella Méndez Corrales, Hector Cori, and Roberto Viquez of DSM Nutritional Products; Jorge Viquez Jimenez, Executive President, Carlos Gonzalez Marroquin and Jorge Guido Delgado of Vigui; personnel of Industry Miramar; José Francisco Solera, the Grupo NTQ; Dr. Luis Tacsan Chen, Director, and Dr. Melany Ascencio, Nutritionist, of the Research and Technological Development in Health at the Ministry of Health; and Dr. Thelma Alfaro, Head, Micronutrient Reference Center, Dr. Patricia Allen, and Dr. Elena Compos of the Costa Rican Institute of Research and Teaching in Nutrition and Health (INCIENSA by its acronym in Spanish).

In the United States, the team interviewed Monte White, President and CEO, and Patrick Clark, Vice President, Sales & Marketing for Research Products Inc., in Salina, Kansas; Sam Wright, President, Wright Enrichment Inc.; and Keith L. Hargrove, Vice President of Manufacturing and Technology, and Mr. Ken Cox, Farmers' Rice Cooperative, Sacramento, California.

ABBREVIATIONS AND ACRONYMS

AED	Academy for Educational Development
CDC	Centers for Disease Control
COFCO	China National Cereals, Oils and Foodstuffs Corporate
EAR	estimated average requirement
FRC	Farmers' Rice Cooperative
FNRI-DOST	Food and Nutrition Research Institute-Dept. of Science and Technology (Philippines)
IFR	iron-fortified rice
IRP	iron-rice premix
IFT	Institute of Food Technologists
NFA	National Food Authority (Philippines)
PNDC	Public Nutrition and Development Center (China)
RPC	Research Products Company

CONTENTS

Acknowledgments

Abbreviations and Acronyms

Executive Summary	7
I Description and Objectives of the Study	10
II Summary of Findings	11
III General Analysis and Conclusions	27
IV Recommendations	29

Tables

Table 1: Rice production, trade, availability, and consumption in four countries	11
Table 2: General characteristics of the rice milling industry	12
Table 3: Amount of Micronutrients Added to Retail Rice in the Existent Program	17
Table 4: Content of Micronutrients in the Rice-Premixes of the Existent Programs	18
Table 5: Comparison of Programs and Quality of Rice- and Micronutrient- Premixes	20
Table 6: General characteristics of the fortification conditions and costs	21
Table 7: A Theoretical Fortification Formulation for Comparison Purposes	22
Table 8: Estimation of the Additional Micronutrient Intakes by Consuming Fortified Rice Accordingly to Formulation	23
Table 9: Comparison of the conditions of the premixes production by extrusion, coating and dusting	24
Table 10: Comparison of the conditions of rice fortification using rice-premixes and micronutrient premixes (dusting)	26

Annexes

Annex 1	Members of the Field Teams	32
Annex 2	China Report	34
Annex 3	Philippines Report	46
Annex 4	Costa Rica Report	57
Annex 5	United States Report	67

EXECUTIVE SUMMARY

A2Z: The USAID Micronutrient and Child Blindness Project collaborated with the Institute of Food Technologists (IFT) to conduct an assessment of rice fortification in China, Costa Rica, the Philippines, and the United States. These countries illustrate various contexts for rice fortification including high versus low per capita rice consumption, net exporter versus net importer of rice, mandatory versus voluntary fortification, and national scale versus limited fortification. Two-person teams (an agricultural economist and a food technologist) visited the study countries in 2007 and met with industry and government representatives and other stakeholders. The objectives of the assessment were to:

- establish a baseline of rice fortification practices, industrial requirements, and the needed investment and recurrent costs for rice manufacturers; and
- assess the technical and economical feasibility and the implications of the introduction of rice fortification in developing countries.

Rice Fortification Technologies and Characteristics of the Fortified Rice

The teams observed four types of rice fortification technology:

1. *Hot extrusion* passes dough made of rice flour, a fortificant mix, and water through a single or twin screw extruder and cuts it into grain-like structures that resemble rice kernels. This process involves relatively high temperatures (70-110°C) obtained by preconditioning and/or heat transfer through steam heated barrel jackets. It results in fully or partially pre-cooked simulated rice kernels that have similar appearance (sheen and transparency) as regular rice kernels. The teams visited two companies in China and one in the Philippines that used this technology.
2. *Cold extrusion*, a process similar to one used for manufacturing pastas, also produces rice-shaped simulated kernels by passing a dough made of rice flour, a fortificant mix, and water through a simple pasta press. This technology does not utilize any additional thermal energy input other than the heat generated during the process itself, and is primarily a low temperature (below 70°C), forming process resulting in grains that are uncooked, opaque, and easier to differentiate from regular rice kernels. One of the firms visited in Costa Rica uses this process.
3. *Coating* combines the fortificant mix with ingredients such as waxes and gums. The mixture is sprayed to the rice on the surface of grain kernels in several layers to form the rice-premix and then is blended with polished rice. Manufacturers in Costa Rica, the Philippines, and the United States use this process.
4. *Dusting*, observed only in the U.S., involves dusting the polished rice grains with the powder form of the micronutrient premix. The fortificants stick to the grain surface because of electrostatic forces.

The first three processes produce a rice-premix that is blended with retail rice (polished rice packaged at rice mills). The fourth applies a micronutrient-premix directly to rice. Both extrusion technologies described above maintain a low shear process with the help of relatively high in-

barrel moisture content (30-35% wet basis) and/or special screw design. In addition to technological differences in production, there are other variations in fortified rice.

- *Number and source of micronutrients.* With the exception of Costa Rica, the other countries visited included iron in the rice fortification although the source of the iron varied. The Philippines added only iron while the other countries added between four to seven vitamins and minerals. With some minor differences, the micronutrient content of the fortified rice was similar regardless of the method used for fortification.
- *Characteristics of the Rice- and Micronutrient Premixes.* The artificial and fortified kernels produced through hot extrusion share similar properties with natural grains (transparency, sheen, consistency, and flavor). The fortified kernels from cold extrusion are opaque and slightly off-color. Coated kernels often have a distinctive color, smell, and taste that are objectionable to some consumers. Dusted kernels lose the micronutrient-premix on their surface with rinsing and washing; hence, this type of fortification is unsuitable for developing countries where rice is washed and rinsed before cooking.
- *Costs.* Of the four methods, dusting is the least expensive and hot extrusion is the most expensive, although the latter produces the best quality product and hence improves acceptance by the consumer. Based on theoretical cost comparisons, the final cost of the rice-premix would be more or less the same regardless of the number and type of micronutrients added. From 67 percent to 74 percent of the total cost of the rice-premixes produced by any method depends on factors not associated with the fortificant mix such as purchasing the rice grains, manufacturing the rice flour, and investing in equipment and facilities.

Recommendations

Based on the four-country assessment and theoretical cost comparisons, the study teams recommend that the following factors be considered before initiating a rice fortification program.

- *Consumer preferences.* If the target population demands homogeneous grains in form, size, consistency, flavor, and color, the hot extrusion technology may be the only acceptable method. If the target population is less demanding or the rice is heterogeneous in color, consumers may accept rice fortified through cold extrusion or good coating technologies. If the target population likes the distinctive properties of fortified rice (color, e.g.) because they indicate that the rice is fortified and more nutritious, all technologies except dusting and bad-quality coating could be viable options.
- *Levels of consumption.* If rice consumption by the target population is less than 100 g/day (36 kg/year), the introduction of rice fortification using rice-premixes is not worth the investment.
- *Coverage and Cost.* If rice fortification is to achieve broad reach and mass production, hot extrusion is the preferred technology because of its higher quality product. The cost of the hot-extruded product is 10 percent to 25 percent higher than the cost for cold-extruded and coated products, respectively. For relatively small projects or pilot trials, cold extrusion and coating technologies could be a practical and less expensive way to

get started. Overall, the cost of rice fortification could be reduced if the processing equipment could be produced locally or regionally in neighboring countries. Currently, most machines used on the visited sites are imported (from Japan and the U.S.) at high cost.

- *Hot extrusion facilities.* A factory of this type should only be considered if the estimated demand for the rice-premix is at least 1,500 MT/year, which is sufficient to fortify 150,000-300,000 MT/year of rice. The initial investment in a factory for hot extrusion is around US\$ 4 million.
- *Cold extrusion and coating facilities.* Factories that produce rice-premix using these technologies are appropriate when the rice-premix demand is at least 300 MT/year, which is sufficient to fortify 30,000-60,000 MT/year of rice. The initial investments of factories using these types of technology are approximately US\$0.75 and US\$0.30 million, respectively.
- *Mill size.* Rice fortification by many small mills increases the cost of the program and presents logistical difficulties for delivery of the rice premixes, quality control, and governmental inspection. Large, centralized mills are more cost efficient. Rice fortification is practical to implement in mills whose production is larger than 5 MT/hour (i.e. 15,000 MT/year).
- *Fortification formula.* Rice fortification is relatively expensive as compared with the fortification of other types of foods because of the costs associated with the synthesis of artificial kernels or the coating process of natural kernels. Unlike fortification of other staples, the price of the fortificants (source of micronutrients) has a small impact on the overall cost. Therefore, to make the investment worthy, the addition of several micronutrients that are insufficient in the diet should be considered.
- *Overall cost.* Independent of the fortification formula and the fortification process, it is estimated that rice-premixes have a production cost of about US\$1/kg, and commercial prices around US\$2/kg. Rice-premixes are usually designed to be diluted 1:100 to 1:200, and they represent around 90 percent of the total fortification cost. Consequently, the cost of rice fortification is estimated between US\$10/MT and US\$20/MT. This means that the cost of fortified rice would be US\$0.36-0.73 or US\$1.09-2.18 more per year than the cost of unfortified rice for consumers with usual rice intakes of 100 or 300 g/day, respectively.
- *Financial sustainability.* Although an increment of 2 percent to 4 percent of the current retail price of rice due to fortification is not a limiting factor with branded rice aimed to high-end market consumers, it may be a constraint for implementing mass-fortification programs. If this is the case, countries may still consider establishing subsidized social programs targeted to vulnerable groups.

I. DESCRIPTION AND OBJECTIVES OF THE STUDY

Objectives

A2Z: The USAID Micronutrient and Child Blindness Project collaborated with the Institute of Food Technologists (IFT) to conduct a four-country assessment on rice fortification in 2007. A2Z is managed by the Academy for Educational Development (AED) under a five-year Cooperative Agreement with the United States Agency for International Development. The four countries studied were China, Costa Rica, and the Philippines, representing developing countries, and the United States for comparison purposes.

The objectives of the study were: to establish a baseline of rice fortification practices, industrial requirements, and the needed investment and recurrent costs for rice manufacturers; and to assess the technical and economical feasibility and the implications of the introduction of rice fortification in developing countries.

Among the issues addressed in this assessment are:

- Market for rice, industry structure, consumption, distribution, and the proportion of the rice supply available for fortification
- Technology types for rice fortification; capabilities and suitability of rice premix production; equipment type and size, capacity, and cost; physical plant; and human resources
- Conditions and requirements that the rice industry must comply with if fortification is to be introduced in an efficient and economical way, taking into account the volume of production, size and type of equipment, financial investment, and financial margins
- Cost analysis of rice fortification for each country: feasibility, affordability, and how to make it financially viable

Research teams

IFT provided two teams of technical experts. Agricultural economist Dr. Eric J. Wailes and food technologist Dr. Tung-Ching Lee visited China and the Philippines. Agricultural economist Dr. Gail L. Cramer and agricultural technologist Dr. Sajid Alavi reviewed the rice fortification experiences of Costa Rica and visited some rice facilities in the U.S. Details about the professional background and experience of the team members appear in **Annex 1**.

Each team prepared individual country reports (**Annexes 2 to 5**). The gathered information was synthesized in one common report, written and edited by Dr. Betty Bugusu and Dr. Jennifer McEntire of IFT, and Dr. Omar Dary and Ms. Luann Martin from AED. Members of the field teams participated in the discussions and review of the final document.

II. SUMMARY OF FINDINGS

This section summarizes the findings of the four country reports, focusing on rice consumption and fortification practices, technologies used for rice fortification, components and characteristics of the rice- and micronutrient premixes, and costs associated with rice fortification,

1. Rice Production, Availability, Milling Structure and Consumption

Demographic characteristics, rice production, and consumption varied greatly in the countries visited. For example, Costa Rica, with a population of 4 million, imports almost half of the rice that is consumed while China, with a population of 1.3 billion, is the world's largest rice producer. **Table 1** summarizes the contrasting and comparative features of the four countries. The U.S, which is a net exporter, has a very low rate of rice consumption compared with the developing countries. Of the four countries, annual per capita rice consumption ranged from 14 kg/year in the U.S. to 128 kg/year in the Philippines. Rice is the main staple in the three developing countries with daily per capita consumption levels at 150 g/day in Costa Rica, 240 g/day in China, and 350 g/day in the Philippines.

Table 1
Rice production, trade, availability, and consumption in four countries

Country	Population (millions)	% Population consuming commercial rice	Estimated Rice Production, Trade and Availability (thousands MT)				Rice consumption (kg/year per capita)
			Production	Importation	Exportation	Balance	
China	1,322	~ 40%	125,000	-	9,000	116,000	88
The Philippines	91	~ 60%	10,000	1,600	-	11,600	128
Costa Rica ¹	4	> 90%	133	126	39	220	55
USA	300	> 95%	8,800	-	4,600	4,200	14

In China and the Philippines, large portions of the population, about 60 percent and 40 percent, respectively, consume rice processed locally by small mills. Rice fortification requires processing by formal and centralized mills, so it will be very difficult for a sizable proportion of the population in these countries to have access to fortified rice. **Table 2** presents the existent structure of the rice milling industries as described to the teams. China and the Philippines have only a few mills with a production capacity greater than 3-5 metric tons (MT) per hour. This condition limits the potential of rice fortification because much of the population with nutrient deficiencies is not served by these rice mills. Nevertheless, because of the large population of China and the Philippines, many individuals could benefit if the large mills fortified rice. In

¹ The table shows the retail rice, calculated as 70% of the paddy rice.

Costa Rica and the U.S., most consumers purchase rice that is processed in a few relatively large mills.

Table 2
General characteristics of the rice milling industry

Country	Characteristics of the rice mills		Population served per type of mill
	Number	Hourly Production (MT)	
China	300,000	1 – 5	5,000
	200 – 300	5 – 10	200,000
	10	80 – 100	2,500,000
The Philippines	9,000	< 3	5,000
	1,000	3 – 10	50,000
Costa Rica	25	5 – 10	160,000
USA	20 – 30	> 50	10,000,000

2. Current Rice Fortification Practices

Rice fortification is occurring in all of the countries visited, although the reasons for fortification vary.

In China, rice fortification is motivated by two different reasons. A market-driven approach aims at high-end consumers who purchase vitamins and health foods and might be willing to pay for the higher price of fortified rice. This is the approach of an alliance of two transnational corporations, DSM and Buhler, as well as the China National Cereals, Oils, and Foodstuffs Corporate (COFCO), which trades most cereals and oilseeds in the country. The other approach is socially motivated and promoted by PATH, an international non-profit organization. PATH advocates for the use of fortified rice in government feeding programs for vulnerable groups. The joint DSM/Buhler rice fortification effort, known as Wuxi NutriRice Co., was launched in late June 2007. COFCO added a line for rice fortification to one of its existing rice mills in Jiangsu province. UltraRice™, the product promoted by PATH, is already marketed in Brazil, Colombia, and India. PATH conducted pilot-scale studies in 2004 in China and is currently looking for commercial partners.

In the Philippines, the promulgation of mandatory regulations in 2000 prompted the introduction of rice fortification programs. Although the Filipino regulations stipulated compulsory rice fortification by November 2004, fortified rice represents approximately 2-4 percent of national rice consumption. Most of the fortified rice is handled by the National Food Authority (NFA), a quasi-governmental institution with the mandate for food security and price stabilization and regulatory powers over grain business. The NFA distributes approximately 15 percent of all rice consumed in the Philippines. Most of the fortified rice is imported from Viet Nam, although some of the rice is fortified in the Philippines using a rice-premix produced by the Wright Company in the United States, shipped to Viet Nam, and then exported to the Philippines. To date, an estimated 15-25 percent of the NFA rice is fortified. Some private brands of rice are

being fortified in the Philippines, but the volume is very small. Fortified rice is rarely found in the market.

In Costa Rica, mandatory regulations on rice fortification were issued in 2001. In contrast to the Philippines, authorities reported that most of the rice sold in the country follows the standard, although according to anecdotal statements, an estimated 5-20 percent of the rice sold in Costa Rica is not fortified or fails to meet the minimum mandated levels due to lack of a strict regulatory and testing mechanism. Nevertheless, the Costa Rican program is ongoing at the national level, and all mills in the country are carrying out fortification.

In the United States, an estimated 70 percent of the rice available in the market is fortified although rice fortification is for the most part voluntary. Six states do mandate rice fortification, but the practice may not be strictly enforced because of industry concerns about the vitamin-like medicinal odor of the product. Compliance of the fortification standards is unknown.

3. Types of Fortification Technologies

The type and the degree of sophistication of fortification technologies, the various micronutrients added to the rice, and the level of fortification vary among the countries. Four major methods for rice fortification were identified: hot extrusion, cold extrusion, coating, and dusting. The terminology used in this report is shown in Box 1.

Hot extrusion

This extrusion method is currently applied by Wuxi NutriRice Co. (DSM/Buhler) and COFCO in China and by Superlative Snacks Inc. in the Philippines. Commonly used equipment in the extrusion process includes a hammermill for rice flour production, mixers, single or twin screw extruders, and dryers. In China, DSM/Buhler NutriRice Co. and COFCO operate similar equipment (a twin screw extruder fitted with a steam and water preconditioning system) manufactured by Buhler, the leading rice milling equipment manufacturer in Asia. Their process uses relatively high temperature (70-110°C) in combination with low shear, resulting in a product with very similar properties (sheen, transparency, consistency and flavor) to those of natural rice grains. The rice flour (which may be obtained from broken rice kernels or poor quality rice) is mixed with the fortificant mix, water, binding agents and emulsifiers before passing through the extruder. The dough moves through the extruder via one or more screws, experiencing increased pressure, shear, and heat during the process. Attachments at the end of the extruder shape and cut the paste into grain-like structures resembling rice kernels. The higher temperatures are obtained by steam preconditioning prior to extrusion and/ or heat transfer through heated barrel jackets, and leads to fully or partially pre-cooked simulated rice kernels.

Box 1. Fortification Terminology

Fortificant: source of each micronutrient

Fortificant mix: blend of all the fortificants

Micronutrient-premix: fortificant mix ready for use directly in rice fortification

Rice-premix: rice grains highly fortified (x100 to x200) with the fortificant mix

Retail rice: polished rice packaged at the rice mills

Fortified rice: retail rice combined with micronutrient premix or the rice-premix

In China, the capacity of both COFCO and Wuxi NutriRice Co. is approximately 5 MT/day of rice-premix, i.e. 1,500 MT/year. In the Philippines, the capacity of Superlative Snacks is smaller with an annual production of 300 MT. The fortified rice-premix is formulated for dilution at either 1:100 (i.e. 10 kilograms per metric ton of fortified rice) in China, or 1:200 (i.e. 5 kilograms per metric ton of fortified rice) in the Philippines. The latter dilution may be applied only when the production and consumption of rice are large; otherwise, the blend of the rice-premix with the retail rice may deliver very heterogeneous amounts of micronutrients to the consumer. On the other hand, to avoid changes in the color or stability of a more concentrated rice-premix, the type and amount of micronutrients should not be too high. .

Cold extrusion

This technology is similar to the one described above, except it utilizes a simple forming extruder also called a pasta press, which does not involve any additional thermal energy input other than the heat generated during the process itself. It is primarily a low temperature (below 70°C) and low shear, forming process resulting in grains that are uncooked, opaque and easier to differentiate from regular rice kernels.

PATH uses a similar method, which was developed by Bon Dente International to produce UltraRice™ premix. Their process is also similar to the one used for manufacturing pastas. Antioxidants are added as part of the ingredients of the synthetic rice kernels to improve the stability of the vitamins. The process involves combining a fortificant mix with rice flour dough, extruding, cutting into rice-shaped grains, and drying. The resultant product resembles natural milled rice grains in size and shape, although it has a slightly softer consistency and is more opaque than natural rice kernels.

Vigui, in Costa Rica, has a similar operation. The equipment includes a hammermill, pasta press (Pavan, Italy), a perforated belt for pre-drying (Italy), and large trays for final drying. The rice flour is mixed with 2 percent of the fortificant mix, and water is added to adjust the overall moisture to about 35 percent (wet basis) in batch mixers. The wet flour is transferred to the pasta press where it is reformed into rice-like grains using a specially designed screw and die, and a continuously acting rotational knife. The re-fabricated rice-premix grains are pre-dried in a perforated belt (9 passes) continuous drying system using air at 70°C for 2-2.5 hours. The partially dried rice-premix is then stacked in trays and placed in conditioning chambers for 8 hours for final drying at 60-70°C. The dried rice-premix is transferred to a concrete storage silo before bagging and storage in a warehouse.

Vigui is a sub-contractor to DSM for production of fortified extruded rice (Vitarroz brand) for the Costa Rica market. The company produces 600-650 MT of rice-premix per year at a daily capacity of roughly 2 MT in single shifts of 8 hour per day. This amount meets 60 percent of the Costa Rican demand. The main extrusion equipment is operated only for 1 hour per shift. A total of 100 people are employed at the Vigui plant, of which 11 are directly involved in the production of extruded fortified rice.

The rice-premixes have been formulated for dilutions of 1:100 and 1:200 for the PATH and Vigui products, respectively.

Coating technology

In the coating method, ingredients such as waxes and gums are combined with the fortificant mix to create a liquid which is sprayed to the rice in several layers on the surface of grain kernels to

form the rice-premix. The rice-premix is then blended with retail rice for fortification. The waxes and gums enable the micronutrients to stick to the rice kernel, thus reducing losses when the grains are washed before cooking, which is a common practice in developing countries. The final product is rice covered by a waxy layer; the color depends on the fortificants that are added. This method is being applied in the U.S. and by Group NTQ in Costa Rica.

Research Products Company (RPC) in Salina, Kansas, manufactures a coated rice enrichment premix known as REPCO Type CR-2F. The premix is prepared in batches using a horizontal rotary drum mixer (Rollo-Mixer Mark VI, Continental Products Corp., Milwaukee, WI). The mixer consists of a stainless steel rotating drum (88 inches in diameter) supported by two pillow block bearings. The bearings are supported by a steel frame that sits on a steel support base. The mixer drum has up to 12 spray nozzles for delivering an adhesive coating (ethyl cellulose) and pharmaceutical glaze to the milled rice, and rotates at about 3 rpm to achieve a uniform coating in 2-3 minutes. The mixer is equipped with a packager that automatically fills the coated grain premix into 50 lb bags.

Wright Enrichment Inc. also uses a coating technology. This proprietary technology involves embedding the enrichment in microperforations on the rice surface. The Philippines imports from Viet Nam a coated premix containing ferrous sulfate that is manufactured by Wright.

Grupo NTQ in Costa Rica employs a special mixture that it developed for the coating process called Kuruwax, which is made of palm oil-based wax, gums, and an emulsifier. Two solutions are prepared, one containing only Kuruwax and the other containing Kuruwax and a micronutrient premix in a 1:1 ratio, by dissolving in water at 85°C. A special batch coating drum, modified from drying and cleaning drums used in the milling industry, is then used for applying these solutions onto the surface of rice grains in a five-step (or five-layer) process, with each step involving a coating of the Kuruwax solution followed by a coating of the Kuruwax-premix solution. The coated rice is simultaneously dried in the drum using hot air. The final moisture content of the coated rice is 10 percent (wet basis), and levels of fortificant mix and Kuruwax in the fortified rice are 2.4 percent and 0.2 percent, respectively. A batch process takes about an hour to complete.

CLG-Health in Mindanao, the Philippines, uses a coating method developed in-house that employs agar instead of waxes. The presence of dust in the rice-premix and the strong metallic off-flavor indicate that the coating layer is easily separated from the rice grain. For this reason, this method in its present state, was found unsuitable for rice fortification.

The capacity of RPC's unit is 1800 kg/batch (4000 lb/batch); Wright's capacity is larger. The coating drum of Grupo NTQ in Costa Rica is 500 kg/batch. Approximately 400 MT of rice-premix (Super Grain brand) is produced annually by this group through its subsidiary Kuruba Industries in Costa Rica.

In all observed cases, the rice-premix was formulated for a dilution of 1:200 (i.e. 5 kilograms per metric ton of fortified rice).

Dusting technology

This technology, observed only in the U.S., involves dusting the retail rice grains with the powder form of the micronutrient premix, with the assumption that the fortificants will stick to the grain surface because of electrostatic forces. Consumers are advised that rice fortified with powdered premixes should not be rinsed before or after cooking nor should the rice be cooked in excessive amounts of water and then drained. If this advice is not followed, the enrichment and other water soluble vitamins and minerals will be lost. For this reason, the dusting technique is not appropriate in developing countries where rice is washed and rinsed before cooking.

The dusting method uses a micronutrient premix, which is a blend of the fortificant mix with cornstarch and other ingredients to improve micronutrient stability and premix flowability, as well as dryness and prevention of the formation of aggregates. The dilution that is being used is 1:1,600 (i.e. 625 grams per metric ton of fortified rice). This process is similar to the fortification of flours. Segregation of the micronutrient premix might occur from the rice grains but, it would be difficult to perceive because of the large dilution factor.

4. Micronutrients Added and Levels of Fortification

Table 3 shows the different micronutrients and their levels in the fortified rice of China, the Philippines, Costa Rica, and the United States. China, Costa Rica, and the U.S. fortify rice with at least vitamin B-1, niacin, and folic acid. With the exception of Costa Rica, all of the countries add iron. Iron is added in the form of ferrous sulfate in the Philippines, micronized ferric pyrophosphate in China, and ferric orthophosphate in the United States. Incorporation of zinc, as zinc oxide, seems to be compatible in the rice-premixes because both China and Costa Rica have included this nutrient as part of the fortification formulation. Costa Rica is also adding vitamin E and selenium. Vitamin B-2 (riboflavin) is not included in any of the premixes probably because of its intense yellow color.

Ferrous sulfate is not used as the source of iron in China and the U.S. because of changes in color and adverse reactivity against the other micronutrients in the rice-premixes. Both micronized ferric pyrophosphate and ferric orthophosphate are white powders with low chemical reactivity because of their low water solubility. Despite being more expensive than ferrous sulfate, micronized ferric pyrophosphate was selected in China to avoid discoloration and rancidity in the final product. The micronized ferric pyrophosphate has a better bioavailability than the common forms of ferric pyrophosphate. Ferric orthophosphate is used in the United States for the same technical reasons, but its bioavailability is very low; hence, its use as a fortificant of rice is questionable. Bioavailability was the main motive for the selection of ferrous sulfate in the Philippines. However, the ferrous sulfate-containing kernels are clearly distinguishable from the unfortified rice and may not be acceptable to the consumer.

PATH is considering using as its iron source a commercial micronized and encapsulated form of ferric pyrophosphate, designated as SunActive Fe® by Taiyo, a manufacturing company in Japan. This product is different from that used by DSM/Buhler and COFCO and is claimed to be a better iron source because of better compatibility with the rice sensorial properties and a bioavailability that is about 95 percent that of ferrous sulfate. Currently, this iron source is more expensive than the usual micronized ferric pyrophosphate. One kilogram of the encapsulated form costs US\$125/kg with an iron content of 12.5 percent while the micronized ferric pyrophosphate used by DSM/Buhler and COFCO costs US\$10.80/kg with an iron content of 25

percent. This is a difference of 23 times in terms of equal amounts of iron content; therefore, it is still uncertain if the encapsulated form of micronized ferric pyrophosphate can be used in a program context.

Table 3
Amount of Micronutrients Added to Retail Rice in the Existent Programs

Extrusion and Dusting* Technologies		Coating Technology	
Company (Country)	Micronutrients (Fortificant) - mg/kg	Micronutrients (Fortificant) - mg/kg	Company (Country)
DSM/Buhler ² & COFCO (China)	Vit. B-1 – 3.5 Niacin – 40.0 Folic Acid – 2.0 Iron (Micronized Ferric Pyrophosphate)– 24.0 Zinc (Zinc Oxide) – 25.0	Iron (Ferrous Sulfate) – 36.0	Wright (USA for the Philippines)
Superlative Snacks (Philippines)	Iron (Ferrous Sulfate) – 60.0	Iron (Ferrous Sulfate) – 60.0	CLG Health Food Products (Philippines)
Vigui – with DSM support (Costa Rica)	Vit. B-1 – 6.0 Niacin – 50.0 Folic Acid – 1.8 Vit. B-12 – 0.010 Vit. E – 15 IU Selenium – 0.1 Zinc (Zinc Oxide) – 19.0	Vit. B-1 – 6.0 Niacin – 50.0 Folic Acid – 1.8 Vit. B-12 – 0.010 Vit. E – 15 IU Selenium – 0.1 Zinc (Zinc Oxide) – 19.0	Group NTQ and Kuruba with Fortitech support (Costa Rica)
Wright* & RPC MR-16F* (USA)	Vit. B-1 – 4.4 Niacin – 35.2 Folic Acid – 1.6 Iron (Ferric Orthophosphate) – 46.3	Vit. B-1 – 4.0 Niacin – 32.0 Folic Acid – 1.4 Iron (Ferric Orthophosphate) – 26.0	Wright & RPC CR-2F (USA)

Dry forms of vitamin A as retinyl esters can be added to rice-premixes, with no effect on the color of the fortified rice if added at the proper level. However, in China, Wuxi NutriRice Co. is producing a fortified rice that includes β -carotene (a precursor of vitamin A), which confers a strong yellow color to the synthetic kernels. The company plans to highlight this characteristic in marketing campaigns as a way of making consumers aware of the fortification quality of the product.

Regardless of the method used for fortification, the final micronutrient contents—with some minor differences—are highly similar in all of the fortified rice products.

² Another formulation also contains β -carotene.

5. Characteristics of the Rice- and Micronutrient Premixes

The dusting technology cannot be used in developing countries; therefore, the challenge of rice fortification is to produce highly fortified rice-kernels whose characteristics are very similar to natural rice grains. **Table 4** presents the micronutrient contents that should be incorporated into the rice-premixes (by extrusion or coating) to achieve the micronutrient levels in fortified rice shown in **Table 3**. The micronutrient contents in the fortified rice-premixes are one to two hundred times higher than in the fortified rice because of the dilution factors of 1:100 to 1:200. Nevertheless, the iron content of the Filipino formulation seems too high, especially since the fortificant is ferrous sulfate.

Table 4
Content of Micronutrients in the Rice-Premixes of the Existent Programs

Extrusion and Dusting* Technologies		Coating Technology	
Company (Country)	Micronutrients (Source) - g/kg	Micronutrients (Source) - g/kg	Company (Country)
DSM/Buhler ³ & COFCO (China)	Vit. B-1 – 0.35 Niacin – 4.0 Folic Acid – 0.2 Iron (Micronized Ferric Pyrophosphate) – 2.4 Zinc (Zinc Oxide) – 2.5	Iron (Ferrous Sulfate) – 7.2	Wright (USA for the Philippines)
Superlative Snacks (Philippines)	Iron (Ferrous Sulfate) – 12	Iron (Ferrous Sulfate) – 12	CLG Health Food Products (Philippines)
Vigui – with DSM support ⁴ (Costa Rica)	Vit. B-1 – 1.7 Niacin – 12.0 Folic Acid – 0.50 Vit. B-12 – 0.003 Vit. E – 4000 IU Selenium – 0.022 Zinc (Zinc Oxide) – 4.0	Vit. B-1 – 1.2 Niacin – 10.0 Folic Acid. – 0.36 Vit. B-12 – 0.002 Vit. E – 3000 IU Selenium – 0.021 Zinc (Zinc Oxide) – 3.8	Group NTQ and Kuruba with Fortitech support (Costa Rica)
Wright* & RPC MR-16F* (USA)	Vit. B-1 – 7.0 Niacin – 56.4 Folic Acid – 2.6 Iron (Ferric Orthophosphate) – 74.1	Vit. B-1 – 0.8 Niacin – 6.4 Folic Acid – 0.28 Iron (Ferric Orthophosphate) – 5.2	Wright & RPC CR-2F (USA)

The micronutrient premix used for the dusting technology has higher micronutrient levels, but this is compatible with the dilution 1:1,600 used with this method.

³ Another formulation also contains β -carotene.

⁴ Formulation includes overages of 40% for vitamins B-1, folic acid, vitamin B-12, and vitamin E; 20% for niacin; and 5% for selenium and zinc.

Table 5 (pg. 20) includes the description of the qualities of the different rice- and micronutrient premixes. If one excludes the fortificants that confer strong colors, it is possible to conclude that the best rice-premixes are those produced by hot extrusion. The artificial and fortified kernels are difficult to distinguish except upon close inspection. Cold extrusion produces fortified kernels that, despite being similar in form and shape to the rice grain, are opaque, off color and have a softer consistency than natural rice grains. Rice-premixes produced by cold extrusion are useful for consumers who are not as concerned about the whiteness of the rice or the heterogeneous of rice in terms of color. These are the reasons for the successful use of a rice-premix of this type in Costa Rica.

Coating technologies produce rice-premixes that, if done correctly, may offer a valid alternative to the extrusion technology, especially when only colorless fortificants are used. The fact that the fortificants are attached to the surface of the grain makes the coating technology less acceptable if colored fortificants, such as ferrous sulfate, are used. The product may not appeal to some because of odors of the waxes and solvents remaining in the final product. Moreover, for some coating methods, such as the method developed locally in the Philippines, the adhesion of the fortificant layer is weak, and the micronutrients can be lost after washing and rinsing.

The micronutrient premix used with the dusting technology is a white powder with a strong vitamin odor because of the high content of micronutrients in the premix. However, once the powder is diluted 1:1,600 into the retail rice, the presence of the micronutrient premix is not noticeable.

6. Costs of Rice Fortification in the Existent Programs

Table 6 (pg. 21) summarizes the conditions and costs of different rice fortification programs that were examined. Details of the calculations appear in **Annexes 2 to 5**.

The cost of all rice-premixes was similar independent of the methods of production, micronutrient content, and country. The cost was around US\$1/kg, which suggests that elements other than the fortificant costs have a large influence on the total cost of the rice-premix. The costs of rice fortification ranged from US\$2.40/MT with the dusting method to US\$19.10/MT with the hot extrusion method. However, a direct cost comparison cannot be made because, in addition to distinct fortification technologies, the fortification formulas and the dilution factors were also different. The following section presents a theoretical analysis of the cost of the four different methods to produce the same fortified product.

In the Philippines, hot extrusion and coating methodologies produced similar estimations for the fortification cost for rice (US\$10.95/MT), but the rice-premix by the coating method was slightly less costly than the one used for the hot extrusion method. The same price of the rice-premix was used for the two products (US\$2/kg; and see the **Annex 3**) which accounts for this anomalous result in the estimation of the cost of rice fortification. Part of the explanation is the small size operations currently producing these rice-premixes in the Philippines. In Costa Rica, the price of the rice-premix for the coating method was 30 percent less than the price of the rice-premix for cold extrusion, but the cost difference was reduced to 20 percent when all costs for rice fortification were included.

Comparison of the hot extrusion and the cold extrusion was not possible to make because both methods did not occur in the same country.

The cost of the micronutrient premix used for the dusting technology was three times higher than the cost of the rice-premix for the coating technology because the amount of the micronutrients were 8 to 16 times more in the micronutrient premix than in the rice-premix. However, if the costs of the final products are compared (i.e. cost for rice fortification), the dusting technology was only 2.5 times less expensive than the equivalent coating method.

Table 5
Comparison of Programs and Quality of Rice- and Micronutrient- Premixes

Extrusion and Dusting* Technology			Coating Technology		
Company (Country)	Type of Program	Description of Premix	Description of Premix	Type of Program	Company (Country)
DSM/Buhler & COFCO (China)	Aimed to high-end market consumers.	White and stable. A product with β -carotene is yellowish and unstable after 3 months at 30°C.	Product with a strong golden dark color and off-taste, which is very easily distinguished from unfortified kernels. Losses have been reported after rinse-wash preparation for cooking.	Aimed to social-programs under governmental administration.	Wright (USA for the Philippines)
Superlative Snacks (Philippines)	Aimed to high-end market consumers.	Premix has an off white color that is distinguishable upon close inspection.	The premix has a grayish color with dust and strong off-taste. It is distinguishable from non-fortified rice. Stability has not been measured, but losses during the rinse-wash preparation for cooking might be large.	Responding to national regulation, but indeed with a very small coverage.	CLG-Health Food Products (Philippines)
Vigui – with DSM support (Costa Rica)	National program mandate by government.	Premix is a rice-shaped simulated kernel of yellowish color with no apparent odor that becomes soft in contact with water. It is possible to differentiate from the non-fortified rice based on color. Claimed that losses during washing and cooking are minimal.	Slightly yellowish in color with some vitamin-like odor. It is possible to differentiate the rice-premix from the non-fortified rice based on color. Stability of the micronutrient layer over the grain surface is attained through a 5-layer coating process. Losses during washing have been claimed to be less than 5%.	National program mandate by government.	Group NTQ and Kuruba with Fortitech support (Costa Rica)
Wright* & RPC (USA)	Required if claim of enrichment is done. Compulsory in some states.	White powder with strong vitamin odor. It has the common characteristics of micronutrient premixes for cereal fortification. It can segregate from the rice grain. Rinse-washing for cooking will remove the micronutrient premix.	It is claimed that there is no product odor or color change if the coating process is done correctly. Claimed shelf life is 2 years, but storage time is typically 3 months.	Required if claim of enrichment is done. Compulsory in some states.	Wright & RPC (USA)

Table 6
General characteristics of the fortification conditions and costs

Country	Retail rice price (US\$/ kg)	Technology	Estimated rice-premix cost (US\$/kg)	Dilution Factor ⁵	Estimated cost of rice fortification (US\$/MT)	Retail price increase (%)	Fortification cost per consumer (US\$/year)
China	0.42 – 0.56	Hot extrusion	1.15	1:100	19.10	3.4 – 4.5 %	1.68
The Philippines	0.42 – 0.60	Hot extrusion	1.03	1:200	10.95	1.8 – 2.6 %	1.41
		Coating	0.95	1:200	10.95	1.8 – 2.6 %	1.41
Costa Rica	0.63	Cold-extrusion	1.44	1:200	10.04	1.6 %	0.55
		Coating	0.99	1:200	8.00	1.3 %	0.44
USA	0.50 – 1.00	Coating	0.98	1:200	6.00	0.6 – 1.2 %	0.08
		Dusting	3.30 ⁶	1:1,600	2.40	0.2 – 0.5 %	0.03

If the cost comparison is made relative to the increment of the price, the order of progression is as follows: dusting is less expensive than coating; coating is less expensive than cold extrusion; and cold extrusion is less expensive than hot extrusion. This comparison is possible to make because the retail price of rice in all four countries was surprisingly similar. However, when calculations of annual investment per consumer are done, the values are closely associated with the amount of rice consumed in each country because lower quantities of rice premix, and hence micronutrient intakes, are supplied when rice is consumed in lower amounts. In the U.S., the annual cost per consumer is low, US\$0.03-0.08, because the per capita intake of rice is only 14 kg/year. In the Philippines, where the rice per capita intake is 128 kg/year, the estimated cost of the program is US\$1.41/year per consumer. In China, the cost per person is higher (US\$1.68/year) than the other examples because the dilution was lower, the method used was hot extrusion, and several relatively expensive micronutrients were added.

⁵ Amount of premix per amount of fortified rice.

⁶ Micronutrient-premix, whose dilution is 8-16 times greater than that of the rice-premixes.

7. Theoretical Cost Comparison among the Fortification Technologies to Produce the Same Formulation of Fortified Rice

To compare the four different technologies for rice fortification, as well as to identify the main elements that determine the total cost in each one of them, an analysis was made using a common fortification formulation, described below.

Table 7 presents a theoretical fortification formulation that includes vitamin A (1 mg/kg), vitamin B-1 (5 mg/kg), niacin (40 mg/kg), folic acid (1.0 mg/kg), vitamin B-12 (0.01 mg/kg), iron (24 mg/kg, using micronized ferric pyrophosphate), and zinc (25 mg/kg, using zinc oxide). The same table illustrates that this formula needs the addition of nearly 200 grams of the fortificant mix per each metric ton of fortified rice, with most of the weight (85 percent) coming from the fortificants that are the sources of iron, niacin, and zinc. The fortificant mix should be present in a proportion of 1:5,000 (1,000 kg/0.2 kg = 5,000) in the fortified rice. The table also shows that a fortificant mix of this type costs approximately US\$15/kg, which means that each metric ton of rice would contain an equivalent of US\$3 of the fortificant mix, regardless if it is delivered as a micronutrient mix or as a rice-premix of any type. The sequence of the micronutrient costs in decreasing order is: iron (US\$1.04/MT), vitamin A (US\$0.53/MT), niacin (US\$0.46/MT), vitamin B-12 (US\$0.42/MT), folic acid (US\$0.22/MT), zinc (US\$0.21/MT), and vitamin B-1 (US\$0.15/MT). For simplicity, these estimations did not consider overages.

Table 7
A Theoretical Fortification Formulation for Comparison Purposes

Micronutrients (Fortificant)	Micronutrient content added to rice (mg/kg)	Amount of fortificants ⁷ in the fortified rice (g/MT)	Cost of fortificants in the fortified rice (US\$/MT) ⁸	Amount of fortificants in 1 kg fortificant mix (g)	Fortificant cost in the fortificant mix (US\$/kg)
Vit. A (Dry form-250,000 IU/g)	1.0	13.3	0.53	67	2.68
B-1 (Thiamin Mononitrate)	5.0	6.2	0.15	31	0.76
Niacin (Niacinamide)	40.0	40.4	0.46	204	2.33
Folic Acid	1.0	1.1	0.22	6	1.10
B-12 (0.1 %WS)	0.01	10.0	0.42	51	2.11
Iron (Micronized Ferric Pyrophosphate)	24.0	96.0	1.04	484	5.21

⁷ Fortificants are the micronutrient source. These values were calculated dividing the micronutrient level by the proportion of the micronutrient in the fortificant.

⁸ Using the usual prices in the international market during 2007.

Micronutrients (Fortificant)	Micronutrient content added to rice (mg/kg)	Amount of fortificants ⁷ in the fortified rice (g/MT)	Cost of fortificants in the fortified rice (US\$/MT) ⁸	Amount of fortificants in 1 kg fortificant mix (g)	Fortificant cost in the fortificant mix (US\$/kg)
Zinc (Zinc Oxide)	25.0	31.3	0.21	157	1.06
Totals	-	198.3	\$ 3.03	1000	\$ 15.25

Table 8 shows the potential nutritional impact of consumption of about 200 g/day of fortified rice (using the theoretical formulation presented in **Table 7**) by a woman 19-50 years old whose diet is low in bioavailable minerals. Each micronutrient would contribute the following proportion to the achievement of the Estimated Average Requirement (EAR): iron, 18 percent; vitamin A, 56 percent; zinc, 61 percent; niacin, 74 percent; vitamin B-12, 100 percent; folate, 106 percent; and vitamin B-1, 111 percent. Rice fortified at this level would be a good source of iron (with nearly 20 percent of the EAR) and an excellent source of the rest of micronutrients (providing more than 40 percent of the EAR) for a woman of reproductive age. The annual investment on the fortificant mix would be US\$0.222 per consumer eating 200 g/day of rice.

Table 8
Estimation of the Additional Micronutrient Intakes by Consuming Fortified Rice Accordingly to Formulation

Micronutrients (Fortificant)	Micronutrient content added to rice (mg/kg)	Additional intake in 200 grams of rice (mg/day)	EAR for women 19-50 years old (mg/day) ⁹	% EAR through consumption of 200 g/day rice	Consumer cost (US\$/year) ¹⁰
Vit. A (Dry form-250,000 IU/g)	1.0	0.200	0.357	56 %	0.039
B-1 (Thiamin Mononitrate)	5.0	1.0	0.9	111 %	0.011
Niacin (Niacinamide)	40.0	8.0	10.8	74 %	0.034
Folic Acid	1.0	0.2	0.188 ¹¹	106 %	0.016
B-12 (0.1 %WS)	0.01	0.002	0.002	100 %	0.031
Iron (Micronized Ferric Pyrophosphate)	24.0	4.8	26.5 ¹²	18 %	0.076

⁹ Adapted from values recommended by WHO/FAO for a diet with low bioavailability of minerals.

¹⁰ Annual consumption of rice is 73 kg/year (200 g/day).

¹¹ This value is equivalent to 0.320 micrograms of Dietary Folate Equivalents.

¹² This value corresponds to ferrous sulfate and fumarate. In the case of ferric pyrophosphate, the bioavailability is between 50% and 95% of this value, depending on the quality of the product.

Micronutrients (Fortificant)	Micronutrient content added to rice (mg/kg)	Additional intake in 200 grams of rice (mg/day)	EAR for women 19-50 years old (mg/day) ⁹	% EAR through consumption of 200 g/day rice	Consumer cost (US\$/year) ¹⁰
Zinc (Zinc Oxide)	25.0	5.0	8.2	61 %	0.015
Totals	-	-	-	-	\$ 0.222 ¹³

Table 9 illustrates the use of the theoretical fortification formula based on the models of DSM/Buhler and COFCO in China (hot extrusion), Vigui in Costa Rica (cold extrusion), Group NTQ in Costa Rica (coating), and Wright or RPC in the USA (dusting). Details of the capital and interests, costs of the broken rice for the preparation of the rice flour and other ingredients, and process costs appear in **Annexes 2, 4 and 5**.

Although the production capacities and therefore the capital costs are different, the capital cost of premix production is, in decreasing order of investment, hot extrusion, cold extrusion, coating, and dusting. This deduction is supported by the estimated proportion of the total costs due to capital and interests, which range from 0.01 percent to 20 percent.

Table 9
Comparison of the conditions of the premixes production by extrusion, coating and dusting¹⁴

Technology	Dose on rice (kg/MT)	Annual Production (MT)	Capital Cost (US\$)	Recurrent fortification costs (US\$ - thousands per year)					Premix Cost (US\$/kg)
				Capital and Interests	Fortificant Mix	Rice and other	Process	Total	
Hot Extrusion ¹⁵	10	1,500	3,880,000	350	450	441	483	1,724	\$ 1.15
				(20 %)	(26 %)	(26 %)	(28 %)	(100 %)	
Cold Extrusion ¹⁶	10	730	770,000	69	219	215	259	762	\$ 1.05

¹³ This value represents 15-30% of the total cost of fortification using rice-premix, either by extrusion or coating, or 40-60% using the dusting system (see Tables 9 and 10 for estimating the proportions of the fortificant in the overall cost of the fortified rice).

¹⁴ This formulation assumes that 10 kilograms of rice-premix for the coating or extrusion technologies, or 1 kilogram of micronutrient premix for the dusting technology, are added to 1 metric ton of retail unfortified rice. The dilution rates are 1:100 and 1:1000, respectively. In both cases, the final dilution rate of the fortificants in the rice is 1:5,000, because ~200 grams of the combined fortificants are needed to achieve the proposed micronutrient levels as described in Table 7. The rice-premix is a dilution 1:50 of the fortificant mix (5000/100 = 50); and the micronutrient mix is a dilution 1:5 of the same fortificant mix (5000/1000 = 5). Price of the fortificant mix is assumed as US\$15/kg. Price of broken rice is assumed as US\$0.30/kg, and whole rice as US\$0.50/kg. The coated technology uses half broken rice and half whole rice.

¹⁵ Using the model of DSM/Buhler and COFCO in China.

¹⁶ Using the model of Vigui in Costa Rica.

				(9 %)	(29%)	(28 %)	(34 %)	(100 %)	
Coating ¹⁷	10	430	300,000	27	129	172	61	389	\$ 0.90
				(7 %)	(33 %)	(44 %)	(16 %)	(100 %)	
Dusting ¹⁸	1	2,500	100,000	9	7,500	1,500	2,500	11,509	\$ 4.60
				(0.01 %)	(65 %)	(13 %)	(22 %)	(100%)	

The theoretical model is designed to produce a rice-premix for a 1:100 dilution (10 kilograms of rice-premix per metric ton of fortified rice). Under this condition, the cost of the fortificant mix is in the range of 26 percent to 33 percent of the total cost of the different rice-premixes.

Consequently, in the manufacturing of rice-premixes, other items independent of the fortificant mix have greater effect on the overall cost, so the final cost would be more or less the same independent of the number and the type of the added micronutrients. The estimated cost for all three rice-premixes is around US\$1/kg. The proportional cost due to the fortificant mix could be raised if a higher dilution factor were used, such as 1:200, which would require preparation of a rice-premix with twice the micronutrient content. In this case, however, the cost of the other elements would still remain higher than the cost of the fortificant mix.

For the extrusion technologies, the cost of broken rice for preparing the rice flour and the process costs are as important as the fortificant mix in the overall cost. And even more important is the price differential between broken rice and premium rice, which partially pays for the production of the rice-premix, made with synthetic kernels.

Although the equipment cost (and hence the capital and interests cost) is low for the coating process, the cost of rice grain and other ingredients to prepare the sticking layer of micronutrients that is attached to the surface of the rice grains make this procedure as expensive as the extrusion technologies.

In summary, the costs of manufacturing rice premixes show little variation regardless of the method that is used (hot extrusion, cold extrusion, or coating) and the micronutrient formulation. The economical basis for choosing one method over the other depends on the initial capital investment. The equipment and facilities for hot extrusion are more expensive than those for cold extrusion, and the equipment for cold extrusion is more costly than the equipment for coating. However, the price of the final product—the rice-premix—is similar. In terms of quality, the rice-premix produced by hot extrusion is the highest quality followed by the premix from cold extrusion. Coating produces the lowest quality product. If production is large and funds are not limited, hot extrusion would be the preferred method. In any case, all three alternatives may be viable if consumers are not too concerned about the quality and the whiteness of the rice.

¹⁷ Using the model of the Group NTQ in Costa Rica

¹⁸ Using the model of Wright or RPC in USA. Assuming that process costs are equivalent to US\$1/kg micronutrient premix.

For the dusting method, which uses a micronutrient premix, the cost proportion of the fortificant mix with a dilution of 1:1,000 is 65 percent of the total cost of the premix. In this case, the cost of the most expensive fortificants would greatly influence the final cost of the product.

Table 10 shows that once the costs associated with the use of the rice- or micronutrient premixes in the rice mills are included, and assuming that the price of the premixes is 50 percent of the premix costs, dusting turns out to be the least expensive fortification method. Based on these assumptions, the fortification cost using the dusting method is US\$7.30/MT, which is less than half the cost of any of the other methods using rice-premixes. This cost represents only 1.5 percent of the price of the retail rice (assuming US\$0.50/kg). However, it is important to emphasize here that, for developing countries, dusting is not an option because of the widespread practice of washing and rinsing the rice before cooking.

The same table shows that the cost of the rice-premix is the most important element (88 percent or more) of the rice fortification cost at the rice mill. The total costs in this theoretical model are US\$15.39/MT, US\$17.59/MT and US\$19.09/MT for the coating, cold extrusion, and hot extrusion methods, respectively. These costs would result in a price increase in retail rice equivalent to 3.1 percent, 3.5 percent, and 3.8 percent, respectively. In all of these cases, the cost of the fortificant mix in the fortified rice (in this example: US\$3/MT) would increase the price of rice only by 0.6 percent or less. These calculations suggest that if rice fortification is under consideration, the process should incorporate most of the micronutrients that are lacking in the diet. The addition of a single micronutrient would have more or less the same cost implications as the addition of several micronutrients.

Table 10
Comparison of the conditions of rice fortification using rice-premixes and micronutrient premixes (dusting)¹⁹

Method	Dose of premix on rice (kg/MT)	Price of Premix ²⁰ (US\$/kg)	Capital Cost (US\$) ²¹	Recurrent fortification costs (US\$ - thousands per year)				Fortification Cost (US\$/MT) ²²
				Capital + Interests ²³	Premix	Process/Admo. ²⁴	Total	
Hot Extrusion	10	1.72	200,000	16	5,160	552	5,728	\$ 19.09
				(0.3 %)	(90 %)	(10 %)	(100 %)	

¹⁹ Assuming total production of 300,000 MT/year, and mills with 30,000 MT/year capacity (i.e. approximately 10 MT/hour), which means 10 mills

²⁰ Assuming 50% higher costs than the corresponding costs (see prior table). However, it is valid only if the rice mill purchases the rice-premix; if the rice mill also produces this product, the overall fortification cost is going to be reduced by around 40%.

²¹ Assuming that each mill has 4 lines of production, and that the feeder/blenders have a price of US\$5,000 for rice-premixes and US\$2,000 for micronutrient-premixes.

²² These estimations do not take into account that using rice-premixes the rice mill is adding 10 kilograms of fortified kernels per each metric ton of retail rice. Therefore, some savings in terms of rice weight may be considered.

²³ Assuming that the equipment has a useful life of 20 years, and that the average cost of financing over the 20-year period is 4 % of the total capital value.

²⁴ Assuming that the cost for the dusting system is 20% the cost of the extrusion or coating systems.

Cold Extrusion	10	1.57	200,000	16	4,710	552	5,278	\$ 17.59
				(0.3 %)	(89 %)	(11 %)	(100 %)	
Coating	10	1.35	200,000	16	4,050	552	4,618	\$ 15.39
				(0.3 %)	(88 %)	(12 %)	(100 %)	
Dusting	1	6.90	80,000	6	2,070	110	2,186	\$ 7.30
				(0.3 %)	(95 %)	(5%)	(100%)	

III. GENERAL ANALYSIS AND CONCLUSIONS

This section responds to three basic questions that managers of public health programs will need to consider when deciding how to implement a rice fortification program.

1. Which type of rice fortification technology should our program adopt?

A common practice in developing countries is to wash and rinse rice several times before cooking. For that reason, the dusting technology for rice fortification is inappropriate, as well as other coating methods that do not ensure that the layer containing the micronutrients is strongly bound to the surface of the rice grain.

If the target population will accept only rice with homogeneous grains in form, size, consistency, flavor, and color, then the hot extrusion technology is the only possible method for fortification. However, when the consumer is less demanding regarding the color of rice or its heterogeneity, as is the case in Costa Rica, then the cold extrusion and good coating technologies are valid alternatives. If the strategy is to convince the target population that the rice kernels that are different in appearance are the ones with additional nutritional value, then any of the three methods could be used.

If fortified rice is going to be widely extended and produced in large volumes, then rice-premix using the hot extrusion technologies would be preferable. Although the initial investment is larger than for the cold extrusion and coating technologies, the quality of the final product is much better and the difference in cost of the final product is not too high.

For relatively small projects or for pilot trials, the cold extrusion and coating technologies are practical ways for starting. Many countries already operate pasta factories; hence, it would be easy to request manufacturing of rice-like simulated kernels made with rice flour. The only advantage of the coating technology over the cold extrusion technology is the presence of real rice grains, but the limitation is that micronutrients can be detached from the surface of the rice grain and lost during washing and rinsing. Use of waxes and solvents may also confer some odors and flavors to the fortified kernels. Furthermore, fortificants with some color can cause larger discoloration in coated kernels because they are concentrated on the grain surface.

2. Which micronutrients should be added to the rice-premix?

From 67 percent to 74 percent of the total cost of the rice-premixes manufactured by any method depends on factors not associated with the fortificant mix. Formulation of rice kernels with higher micronutrient content would reduce the proportional difference between the cost of the fortificant mix and the other costs. However, the former will always represent less than half of the overall cost of the rice-premixes, so it does not make sense to add only one or very few micronutrients. Formulation of rice fortification should include most of the micronutrients with intake gaps in the common diet.

Iron sources are by far the most voluminous fortificant in the mixes²⁵, and the iron fortificants that are compatible with the rice color and the stability of the premixes are the most expensive in absolute terms as well as their proportion of the additional estimated average requirement. At present, micronized ferric pyrophosphate appears to be the best iron source to add in the rice premixes. New forms of this compound with higher bioavailability characteristics are being developed, such as SunActive Fe® by Taiyo from Japan. If these new compounds are to be considered for real applications in rice fortification, the price will need to be reduced drastically (to less than US\$15/kg).

If changes in color are unacceptable in the rice-premixes, vitamin B-2 (riboflavin) and β -carotene (as precursor of vitamin A) cannot be added. If the change of color is a desirable feature, as projected by DSM/Buhler in China, then these nutrients could also be incorporated in the rice premixes.

3. How can the financial sustainability of a rice fortification program be improved?

Production of rice-premixes is a relatively expensive process. Even in the absence of micronutrients, the estimated cost of rice fortification, using extruded or coated rice premixes, is between US\$12 to US\$16 per metric ton of rice. The fortificant mix of a comprehensive micronutrient formulation, such as the one described in **Tables 7 and 8**, would only add US\$3/MT to that amount. Therefore, any rice fortification initiative should be implemented with the most cost-efficient mechanisms.

If rice consumption is less than 100 g/day (36 kg/year), introduction of rice fortification using rice-premixes is not worthy of consideration unless smaller size, but still cost-effective, extruders can be adopted. The total investment for facilities similar to the current ones in China is too high in comparison with the potential nutritional impact when the consumption of rice is low.

Installation of hot extrusion facilities should be considered if the estimated demand of rice-premix is at least 1,500 MT/year (5 MT/day), because the initial investment is high. Likewise, cold extrusion and coating facilities should operate only if the production is larger than 300 MT/year (1 MT/day). A hot extrusion factory, of the size mentioned above, would be sufficient to fortify 150,000-300,000 MT/year of rice, and cold extrusion and coating factories with the specified production capacity can fortify around 30,000-60,000 MT/year. These estimations are

²⁵ Calcium would have a larger volume and weight than iron, but calcium fortification is usually considered separately. This mineral has the largest estimated average requirement for humans.

based on a dilution factor of 1:100. If the dilution factor is increased to 1:200, the coverage would double, but the heterogeneity of the fortified rice may increase.

Investment costs for the rice-premix factories with the production capacities mentioned above are around US\$4.0 million, US\$0.75 million, and US\$0.3 million, for hot extrusion, cold extrusion, and coating technologies, respectively. The difference in the cost of the final product of the coating technology would be only 20 percent less than the final product of the most expensive (hot extrusion) technology because other costs elements are more important than capital and interest.

According to calculations presented in **Table 10**, the cost of rice fortification using coating or extrusion technologies, and the fortification formulation of **Table 7**, ranges from US\$15 to US\$20/MT. If one assumes that the price of the retail rice is US\$0.50, increments in the price of retail rice would be 3 percent to 4 percent. Apparently, this increment is not an obstacle for a branded product aimed to high-end market consumers, which COFCO plans to do in China. Fortified rice will be advertised at twice the price of unfortified rice. However, poor consumers—who should be the main target for this type of program—may complain, or the trade system may not be in a position to support such a price rise. Each country should analyze if the existent conditions favor implementation of a fortification program of this type.

Some countries may be interested in subsidizing rice fortification for poor segments of their populations. If one assumes rice fortification costs in the range of US\$10/MT to US\$20/MT, the cost of fortification per beneficiary would be: US\$0.36-0.73/year, US\$0.73-1.46/year, and US\$1.09-2.18/year, for individual rice consumption patterns of 100 g/day, 200 g/day, and 300 g/day, respectively.

Finally, it is important to point out that all of these calculations assume the involvement of large rice mills (more than 5 MT/hour, or more than 15,000 MT/year). Participation of smaller mills will increase the cost of the program and introduce logistical difficulties for delivery of the rice premixes, quality control, and governmental inspection. The presence of many and scattered small mills limits the introduction of a rice fortification program at the national level in many countries and also explains why Costa Rica was able to implement a rice fortification program while the Philippines struggles to do so.

IV. RECOMMENDATIONS

1. In developing countries, washing and rinsing the rice is common before cooking. Under this circumstance, only rice-premixes (kernels of rice carrying high-levels of micronutrients) are appropriate for rice fortification.
2. Countries considering the implementation of a rice fortification project should plan to adopt a multiple-micronutrient formula to tackle several of the micronutrient deficiencies simultaneously, because the cost associated with the fortificant mix (source of micronutrients) represents only 15 percent to 30 percent of the overall cost of the fortified rice using rice-premixes.
3. Thus far, the following micronutrients are compatible with rice fortification: vitamins A and E (dry forms), vitamin B-1, niacin, folic acid, vitamin B-12, zinc (as zinc oxide), iron (as micronized ferric pyrophosphate), and selenium. Incorporation of β -carotene, vitamin B-2, and iron as ferrous sulfate changes the color of the fortified kernels, and they could

be included if the plan is to produce fortified-rice kernels that the consumer can distinguish as fortified.

4. Although the investment cost is larger for a rice-premix factory using the hot extrusion technology, the quality of the product is the most similar to the natural rice grain, and the cost of the final product is only 10 percent to 25 percent higher than the cost for cold extruded and coated products, respectively. Therefore, if the amount of rice to be fortified is larger than 150,000 MT/year, the installation of factories of this type should be contemplated. A US\$ 4.0 million factory could produce around 1,500 MT/year of rice-premix (5 MT/day), which is sufficient to cover 1.5 to 8 million persons depending on the annual pattern of rice consumption and the fortification formula.
5. Cold extrusion or coating technologies are appropriate for small or pilot programs. Factories of rice-premix whose annual capacity is 300-900 MT/year (1-3 MT/day) could be installed with investments of US\$0.75 million for the cold extrusion technology and US\$0.30 million for the coating technology. Factories of this size may cover 0.3 to 2.5 million people depending on the annual pattern of rice consumption and the fortification formula. In any case, extrusion technologies are preferable to the coating technologies because the former use broken rice –which has a lower price than rice grain- and put the micronutrients inside the fortified kernel.
6. Independent of the rice fortification technology and the fortification formula, the estimated cost of the rice-premix is around \$1-2/kg, and the total cost for rice fortification is from US\$10/MT to US\$20/MT. Based on these calculations, the annual investment is US\$0.36-0.73/year for an individual consuming 100 g/day of fortified rice and \$1.09-2.20/year for an individual consuming 300 g/day.
7. Rice fortification would show better cost-efficiency if the rice industry were centralized and the mills involved had production capacities larger than 5 MT/hour (i.e., around 15,000 MT/year). Participation of small mills will not only introduce logistic difficulties but also will increase the cost of the program.

ANNEXES

1. Members of the field teams
2. China report
3. Philippines report
4. Costa Rica report
5. USA report

Annex 1

Professional Background and Experience of the Members of the Field Teams

Tung-Ching Lee, Ph.D., served as the food technologist for the assessments in China and the Philippines. He is a Distinguished Professor (Professor II) of Food Science and Nutrition with the Department of Food Science, at Rutgers University. Dr. Lee received his B.S. in Chemistry, Summa Cum Laude from Tung-Hai University in Taiwan, his M.S. (Food Science) and Ph.D. (Agricultural Chemistry) from the University of California, Davis, California. He is a Certified Nutrition Specialist by U.S. Certification Board for Nutrition Specialists. Dr. Lee's research interests are in food quality enhancement through three main, but overlapping, approaches: 1) molecular mechanism-based chemistry; 2) process technology; and 3) biotechnology. His work focuses on safety and toxicological aspects of food processing, nitrification of food through food processing and fortification technology and bioavailability of micronutrients, research and development of nutraceuticals, nonenzymatic Maillard reaction in foods, seafood science and technology, processing and nutrition of foods for NASA advanced support system on space missions, development of chemical markers for food quality evaluation, biochemistry, chemistry, and nutrition of carotenoids and Vitamin A, food extrusion technology, new food products and new processes development, and applied research programs of food technology and nutrition for developing countries. He has served as a Scientific Editor for the Journal of Food Science since 2000 and has published more than 230 research papers in scientific journals. Dr. Lee was elected as a Fellow of IFT in 1981, Fellow of the American Chemical Society in 1998 and Fellow of the International Academy of Food Science and Technology in 2003. In 2007 he received the prestigious "Babcock-Hart Award" for contributions to food technology that improve public health through nutrition or more nutritious food from IFT and International Life Science Institute. Dr. Lee has also served as research project collaborator and consultant for many U.S. and international institutes and the food industry. Dr. Lee's national and international activities have involved collaborative studies with researchers in thirteen countries on six continents.

Dr. Sajid Alavi served as the food technologist for the assessments in Costa Rica and the United States. He received his B.S. in Agricultural Engineering from Indian Institute of Technology, India in 1995, M.S. in Agricultural and Biological Engineering from Pennsylvania State University, PA in 1997 and Ph.D. in Food Science/Food Engineering from Cornell University, Ithaca, NY in 2001. He joined the Department of Grain Science and Industry at Kansas State University in 2002. Dr. Alavi's research interests are in the area of food engineering and more specifically in extrusion processing of food and feed materials, rheology, food microstructure imaging, and structure-texture relationships. His current research projects include -"non-invasive imaging of food microstructure"; "phase transition analysis and structure formation in biopolymeric packaging materials produced by extrusion processing", "starch based bio-degradable packaging foams" and "floating & sinking aquatic feed using extrusion processing". The Extrusion Center, which is under his supervision, provides to the industry extrusion training through short courses and services for pilot scale trial runs for various products. The Center also caters to the needs of research and course related runs. Dr. Alavi's teaching interests include graduate and undergraduate level courses in Extrusion Processing including: 'Extrusion processing in food & feed industries in (senior level) and 'Advanced extrusion processing' (graduate level).

Dr. Gail L. Cramer was the agricultural economist for the assessments in Costa Rica and the United States. He is currently professor and head of the Department of Agricultural Economics and Agribusiness at Louisiana State University. He was the L.C. Carter Chair Professor in the Department of Agricultural Economics and Agribusiness at the University of Arkansas from 1987 to 2000. Dr. Cramer attained his bachelor's degree from Washington State University in 1963, his master's degree from Michigan State University in 1964, and his Ph.D. in Agricultural Economics from Oregon State University in 1967. Dr. Cramer was appointed an assistant professor in the Department of Agricultural Economics and Economics at Montana State University in 1967. He was promoted to associate professor in 1972 and to full professor in 1976. While at Montana State University, he taught courses in beginning, intermediate, and advanced microeconomics, as well as agricultural marketing and agricultural policy. He was selected for four teaching awards at Montana State University, including the Phi Kappa Phi University-Wide Award in 1980. His primary research assignments were in wheat and rice marketing. He has published more than 200 journal articles and other publications in the general area of grain marketing. Dr. Cramer won the E.G. Nourse Award for outstanding Ph.D. dissertation on cooperative mergers. His other awards include the American Agricultural Economics Association's 1980 Award for Excellence in Quality of Communication, for Agricultural Economics and Agribusiness with Clarence W. Jensen. In 1992, he was selected for the Distinguished Faculty Award for Research and Public Service by the Arkansas Alumni Association. Dr. Cramer's research is domestic and international in scope. His rice research has taken him throughout the world, and he has presented seminars on his research in the Philippines, Japan, Indonesia, Mexico, Taiwan, Australia, Hong Kong, Singapore, Egypt, England, Sri Lanka, and Guyana.

Dr. Eric J. Wailes was the agricultural economist for the assessments in China and the Philippines. He is currently the L.C. Carter Endowed Chair and Professor of Agricultural Economics at the University of Arkansas. Dr. Wailes is a native of Colorado where he was raised on a cash crop and dairy farm. He received a B.S. degree in agricultural economics at Cornell University (with a specialization in tropical agriculture). He served as a Peace Corps Volunteer in Ethiopia for two years where he worked for the Ministry of Agriculture on a national agricultural crop reporting system and management studies of state enterprises in the Ministry of National Resource Development. He received his Ph.D. degree in agricultural economics at Michigan State University with an emphasis on international policy and marketing. Dr. Wailes has been a faculty member in the Department since 1980. He conducts research on agricultural policy, trade, and marketing, with an emphasis on the rice sector. Current research activities include analysis of U.S. and global agricultural policies on Arkansas agriculture; U.S. farm bill (price and income support policies, environmental policy, trade policy, energy policy, biotechnology policy); social acceptability of biotechnology, adoption of biotechnology by farmers; marketing and policy issues of organic foods; economic-engineering analysis of grain drying and storage and rice milling; economics of groundwater depletion and water quality issues in Arkansas; analysis of Arkansas, U.S. and global rice economy, long-term projections, market and policy analysis. He teaches courses in marketing and policy.

Annex 2

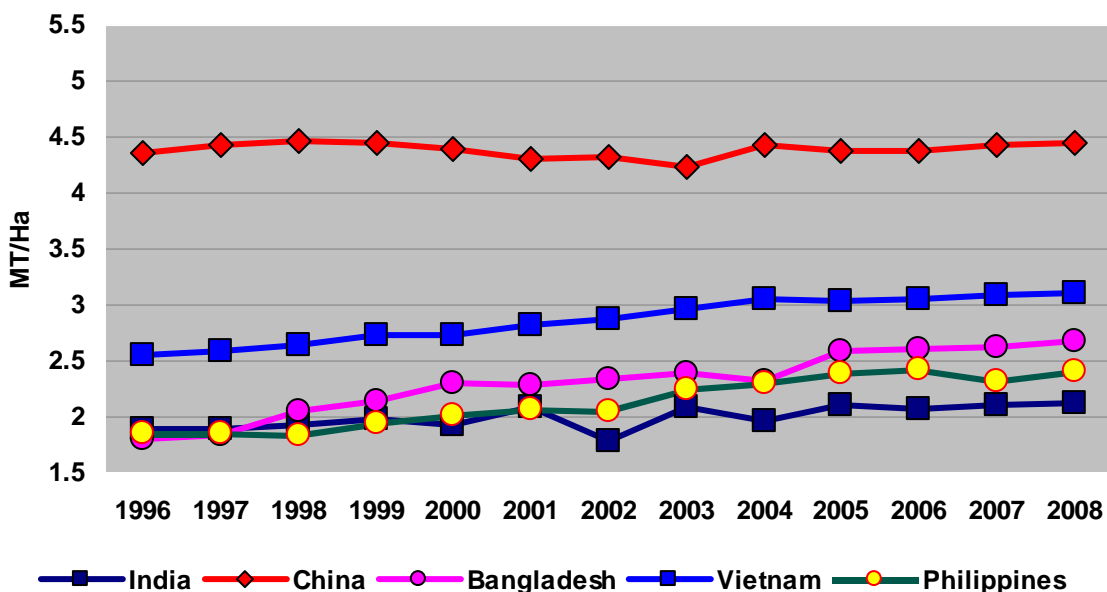
The Status of Rice Fortification in China by Eric Wailes and Tung-Ching Lee

This report is based on stakeholder meetings to assess the status of rice fortification that were held in China by two consultants of the Institute of Food Technologists from June 19-27, 2007.

Rice Availability and Consumption in China

China has succeeded in attaining food self-sufficiency for a population of over 1.3 billion with relatively limited per capita land and water resources. This has been achieved through development and adoption of high yielding crop varieties such as rice and intensive use of fertilizers and pesticides. Rice is currently the leading food staple (125 million MT/year) in most of the country, with higher consumption in the Southern provinces than the Northern provinces. Figures 1 and 2 show the evolution of rice production, trade, and consumption in China.

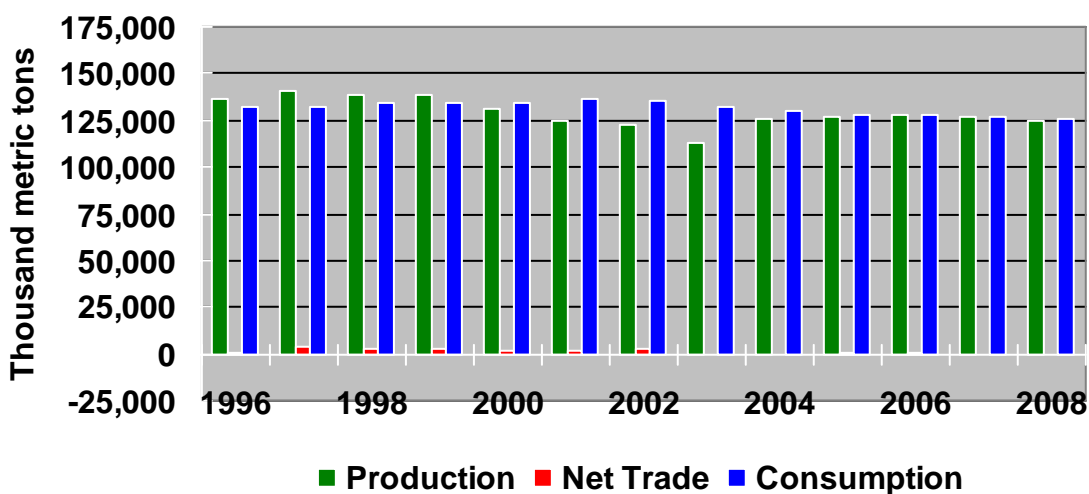
Figure 1. Rice Yield Trends: China and other Asian countries



Source: USDA, FAS Production, Supply & Distribution online data base and Arkansas Global Rice Model

The estimated per capita consumption of rice in China is 88 kg/year. However, the urban population has been replacing this staple with other foods, and the current daily consumption of rice has been estimated for the urban population at only 85 kg/year. The rural population has kept the usual rice consumption at over 100 kg/year. The overall impact in individual rice consumption is a decline over recent years (Figure 3). Today China's rice production levels easily meet its demand, and often China exports excess production.

Figure 2. China Rice Supply and Utilization



Source: USDA, FAS Production, Supply & Distribution online database and Arkansas Global Rice Model

Under the Household Responsibility System, economic reforms began in rural areas of China in the 1980s. Market orientation has now reached essentially all economic sectors in China. With accession to the World Trade Organization (WTO), international trade has also become an important feature of the Chinese economy. Food security, however, continues to be an important policy goal of the government of China. There is also an increasing interest in moving beyond simply providing adequate calories to producing more environmentally sustainable food and improving the quality of the Chinese diet.

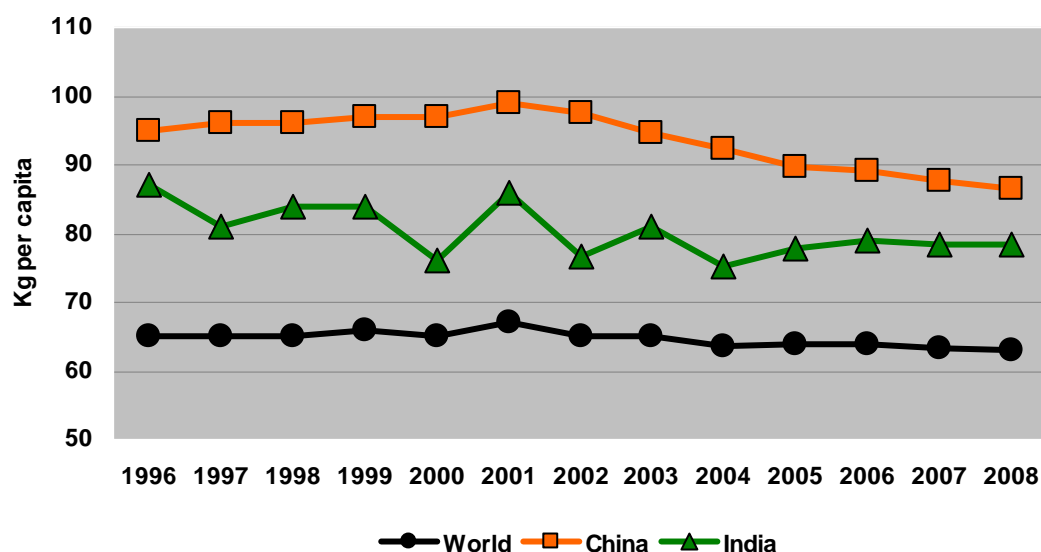
Rice Production and Milling Structure

Many varieties of rice are found in China. This is relevant for fortification because stability of fortificant and process costs can be affected by rice types and varietal differences. Particularly important is the medium grain (round) rice in the northeast provinces of Heilongjiang, Jilin, and Liaoning, which is also the preferred rice by many urban consumers. In the south the long grain varieties are more popular. In the middle provinces, both long and medium grain rice are produced; therefore, segregation for rice types, grades, and standards is required. A small percent of rice is glutinous, used primarily for sweets/desserts. In general, rice milling and supply tends to be provincial. Although there is no national brand, many regional brands appear in the market. Nearly 700,000 metric tons of jasmine rice is imported annually from Thailand.

More than 300,000 rice mills operate in the country. Most of these mills have a capacity of 1 to 5 tons/hour, and an estimated 200-300 mills can produce more than 5 tons/hr and a few (less than 10) as much as 80-100 tons/hour. Official statistics do not report number of mills by size. Many rural families mill their own rice with small portable polishing (kerosene-powered) mills. An estimated 60 percent of rice is milled for home consumption with only 40 percent of the rice entering the commercial channels. This poses a major challenge for rice fortification in China since much of the target population with nutrient deficiencies lives in rural areas and relies more heavily on local custom milling.

Most rice is purchased in bulk 50 kg bags or from bulk bins in wet markets. Urban consumers increasingly are buying rice in supermarkets in 5, 10, and 25 kg bags. Average wholesale price of rice ranges from China Yuan/Ren Min Bi (RMB) 2.2 to 2.9 per kg (US\$ 0.30 to 0.40/kg), and retail prices range from RMB 3 to 4 per kilogram (US\$ 0.42 to 0.56/kg), depending on rice type and quality differences. Consumers typically wash the rice before cooking.

Figure 3. Per Capital Rice Consumption: China, India, World



Rice Fortification in China

Rice fortification is a relatively new initiative in China. A national strategy has not been formulated; however, national standards for iron-fortified rice are being developed. A number of private companies and non-governmental organizations (NGOs) are implementing process technologies, testing the efficacy of fortified rice products, and experimenting in social marketing. No single government ministry or agency is responsible for coordination of food nutrition in China. Key stakeholders can be grouped as China government ministries, agencies and associations, international organizations including NGOs, and private companies (domestic and international). The following organizations are involved in rice fortification.

- The Public Nutrition and Development Center (PNDC), a quasi-government organization that is associated and funded in part by the National Development and Reform Commission under the State Council, is expected to play a critical role in the rice fortification program. The major concern of PNDC is consumer awareness and establishment of fortification standards.
- State Grain Administration is responsible for central government rice stocks and government owned rice mills. Wuhan Cereal Science Research and Design Institute provides technical support for the rice milling sector (public) in China and is charged with drafting fortified rice standards.

- China National Association of Grain Sectors is a trade association formed in 1996 to represent large grain and oilseed processors in China regarding policy, market development, and consumer advocacy.

Technological Capabilities – Current Status

Currently in China, rice fortification has two very different strategies/approaches. One is a market-driven approach aimed at high-end market consumers who spend considerable amounts on vitamins and health foods and who might be willing to pay for the higher price of the fortified rice. This approach is being followed by an alliance of two transnational corporations, DSM and Buhler. DSM has a dominant market share in micronutrients, while Buhler, along with Satake, is the leading rice milling equipment manufacturers in Asia. The China National Cereals, Oils and Foodstuffs Corporate (COFCO), which trades most cereals and oilseeds in the country, is also following the same direction. The other approach is the socially-supported approach promoted by PATH. This international non-profit organization advocates for the use of fortified rice in government feeding programs for vulnerable segments of the population.

For both approaches, the methodology to fortify rice is through addition of fortified simulated artificial kernels produced by extrusion technology. However, the extrusion technologies used are different. DSM/Buhler and COFCO use hot extrusion (relatively high temperature in combination with low shear extrusion) to manufacture a product with very similar properties (form, size, consistency, color, and flavor) to those of the natural rice grain. In addition to the rice flour, coming from milling of broken rice, some emulsifying substances are used for the production of the synthetic and fortified kernels. PATH, on the other hand, is producing UltraRice™ premix (developed by Bon Dente International) that incorporates a cold extrusion step (low temperature in combination with extremely low shear), similar to the process used for manufacturing pastas. Antioxidants are added as part of the ingredients of the synthetic kernels to improve the stability of the vitamins. The process involves combining selected nutrients into rice flour dough, extruding, cutting into rice-shaped grain and drying. The resultant product resembles natural milled rice grains in size, shape, and color but has a slightly softer consistency and is more opaque than the natural rice kernel.

Hot Extrusion: DSM/Buhler and COFCO

The DSM/Buhler joint company rice fortification effort was launched in late June 2007 and is known as Wuxi NutriRice Co. The plan is to manufacture two products: one with and the other without β -carotene (a precursor of vitamin A) along with a spectrum of other vitamins, iron, and zinc. The fortified rice premix is being formulated to be diluted 1:100 over the milled rice (i.e., 10 kilograms per metric ton of rice). Lower (1:50) or higher dilution factors (1:200) can be used depending on the final micronutrient formulations of the synthetic kernels. β -carotene rather than retinol was selected as the source for vitamin A because the plan is to prepare an orange-colored kernel that the consumer can easily distinguish. This feature is going to be stressed as a way to identify the fortified rice with β -carotene and other micronutrients. Vitamin A in the form of retinyl esters can also be added, and the product would be colorless. Micronized ferric pyrophosphate, although more expensive than ferrous sulfate, was selected as the iron source to avoid discoloration and rancidity in the final product. The micronized ferric pyrophosphate has a better bioavailability than the common forms of ferric pyrophosphate.

The micronutrient content of the final product (fortified rice) of the two current formulas is presented below:

Additional Content of Micronutrients in the Fortified Rice by DSM/Buhler

Micronutrient	Fortificant	Additional Content (mg/kg)	
		A	B
Vit. B-1	Thiamine mononitrate	3.5	3.5
Niacin	Niacinamide	40	40
Folate	Folic Acid	2	2
Iron	Micronized Ferric pyrophosphate	24	24
Zinc	Zinc Oxide	25	25
Pro-Vit. A	β- Carotene	-	2

To attain the above specified levels, the amounts of the fortificant mix to be added per metric ton of rice are 175 and 200 grams for products A and B, respectively. They represent dilutions of 1:5714 and 1:5,000 in the milled rice, respectively. When these amounts of the fortificant mixes are formulated to be delivered in a rice-premix with a dilution of 1:100, then the content of the micronutrients in the fortified rice-premix is equivalent to about 3.5 percent for the product A ($5,714/100 = 57.1$ dilution factor; $1/57.1 \times 100 = 1.8$ percent) and 2.0 percent for product B ($5,000/100 = 50$ dilution factor; $1/50 \times 100 = 2.0$ percent).

The first product, A (without β-carotene), is white like regular rice and thus remains unnoticeable when blended with the natural rice. Product A was developed and tested to provide stability under most storage conditions. The second product, B (with β-carotene), has a yellow color that is very distinct from the regular rice. The producers suggest that if the second product is stored for more than 3 months at temperatures above 30 degrees centigrade, the β-carotene becomes unstable.

The DSM/Buhler extrusion facility has a capacity of approximately 5,000 kg per day. That means the facility can produce around 1,500 metric tons of the kernels annually to fortify about 150,000 MT of rice, which would be sufficient to cover at least 1.5 million persons.

The rice fortification facility of COFCO was built as an added line to one of the company's existing rice mills in Jiangsu province. The equipment used is also manufactured by Buhler, and the product is extruded using vitamin-mineral premix containing a formula very similar to the first product (without β-carotene) of DSM/Buhler. The dilution of the rice-premix over the milled rice is 1:100 (i.e. 10 kilograms of premix per metric ton of rice).

The premix factory of COFCO has a similar production capacity as that of DSM/Buhler.

Cold Extrusion: PATH UltraRice™ Technology

PATH is promoting fortified extruded rice called UltraRice worldwide, but mainly in Brazil, Colombia, India and China. PATH is considering using as the source of iron a commercial micronized and encapsulated form of ferric pyrophosphate, designated as SunActive Fe® by the manufacturing company, Taiyo from Japan. This iron source is claimed to have better compatibility with the rice sensorial properties and a bioavailability that is about 95 percent that of ferrous sulfate. Currently, the micronized and encapsulated form of ferric pyrophosphate is more expensive than the usual form used by DSM/Buhler and COFCO. One kilogram of the encapsulated form costs US\$125/kg and an iron content of 12.5 percent compared with US\$10.80/kg and an iron content of 25 percent for the usual micronized ferric pyrophosphate. This is a difference of 23 times in terms of equal amounts of iron content. For this reason it is still uncertain if the micronized and encapsulated form can be used in fortification programs. PATH conducted pilot-scale technology transfer in 2004 and is currently looking for commercial partners for their product.

The PATH fortified rice-premix is being formulated to be diluted 1:100 over the milled rice (i.e., 10 kilograms per metric ton of rice). This means that a rice-premix factory with a capacity of 5,000 kg/day would be needed to cover 1.5 million people.

Cost Associated with Fortification

Both the DSM/Buhler and the COFCO premix factories needed to invest approximately US\$ 4 million. The capital investment for a cold extrusion factory (PATH-type) is around US\$ 3 million. The capital and recurrent cost for these facilities are given in Table 1. The cost of producing the rice-premix using the hot extrusion system in China is around US\$1.15/kg. This cost is slightly higher than the estimated cost (US\$1.05) for the rice-premix manufactured by the cold extrusion system. The difference between the two systems is the type of equipment that is required; the cost is lower for the cold extrusion method than for the hot extrusion method. However, because the capital and the interest costs represent only 15-20 percent of the overall cost of the final product, the final influence of the equipment cost is small and even negligible. Therefore, it seems that the choice between one process over the other depends on the decision about how much to invest at the beginning of the operation.

Table 2 presents the estimations of rice fortification using the dilution factor of 1:100 in both types of rice-premixes. The product used by DSM/Buhler or COFCO costs US\$19.09/MT, while the product from a system similar to that promoted by PATH costs US\$17.09/MT. COFCO estimated that the approximate added cost for rice fortification was RMB 1,000 per metric ton (US\$139/metric ton). This estimation may include other costs such as advertising and quality control, but it seems to be highly inflated. In any case, COFCO is planning to promote the fortified rice in high-end consumer markets and sell at a price of RMB 7-8/kg (US\$ 0.98 - \$1.10). This proposed price is double that of the ordinary milled retail prices of RMB 3-4/kg (US\$ 0.42-0.56) over the past several years. COFCO views its efforts in developing rice-fortified products as proprietary and as such was unwilling to provide detailed equipment and processing costs. For this reason, the cost estimates presented in this report should be used with caution.

Based on the calculations made in this report, it is possible to conclude that the fortification of rice in China is going to increase the current price of the grain (assuming US\$0.50/kg) by 3.5-4.0

percent, which would mean an annual additional cost of around US\$1.50-1.70 per consumer. However, it is important to point out that this calculation is valid if rice fortification takes place in large mills (capacity larger than 2,500 MT/month or larger than 10 MT/hour). Participation of small mills would raise these estimations because of the need for additional equipment in the rice mills and the cost of delivery and supervision.

No detailed investment and recurrent costs for PATH Ultra Rice were available to the team. No PATH facilities were visited nor are there any facilities in operation in China to the best of our knowledge. The presented costs are based on mere estimates.

Assessment of Strengths and Weakness of Current Rice Fortification Program in China

China recognizes two potential channels for rice fortification.

1. *Market-based approach.* There is strong support and encouragement for market-based rice fortification companies. Both the DSM/Buhler and COFCO initiatives are viewed as serious attempts to test the marketplace for acceptance and willingness to pay for a high-priced rice. It appears that the target for this market will initially be Jiangsu Province/Shanghai markets where consumers are relatively wealthy and educated. DSM/Buhler will need to develop clients/rice millers with distribution and market share in these markets. The Wuxi NutriRice Company (DSM/Buhler) also envisions accessing the lower income consumer market with their white fortified rice. This market is believed to be more critical regarding color issues. Price differentials likely will be needed to penetrate both markets. COFCO is going to use their own label to market their product. COFCO envisions accessing the high-end market and plans to price their product at a premium with the need to show profitability.
2. *Government-based approach.* PNDC will play a key role if the government is to get involved in providing fortified rice to the extremely poor segment of the population (25 million). This program will likely require technical and financial assistance from NGOs and research organizations such as PATH, GAIN, and UNICEF. This population segment is primarily rural and does not typically purchase rice from commercial food outlets.

In any case, three promising conditions for food fortification in China are as follows:

1. The institutional framework is beginning to develop, although mandatory rice fortification is unlikely because of the significant logistical and institutional constraints.
2. Technological capability to support rice fortification is available through a number of agencies including PNDC, CDC, and many Universities.
3. Strong capability of food machine designing and manufacturing companies exists (e.g., MUYANG Group, Co., LTD in Jiangsu). The MUYANG Group can design and manufacture system and equipments for fortification at different levels (small village, regional, and central center, etc.).

We also identified three conditions that need to be addressed if the program is to be successful.

1. The decentralized rice milling industry is characterized by a few large mills and many small mills. Fortification is most feasible at a large scale; cost-effectiveness and capacity for Quality Assurance is significantly reduced at a small scale, where many of the most

vulnerable populations access food. Quality control and enforcement could be a major problem.

2. The government has not encouraged or supported enactment of a food fortification policy; thus, enthusiasm for the production of a nutritionally enhanced product is not high.
3. The choice of an appropriate iron fortificant has not been clarified.

General Recommendations:

- China should utilize the strong capability of local food machine designing and manufacturing companies (e.g., MUYANG Group, Co., LTD in Jiangsu) that can design and manufacture system and equipments for fortification at different levels (small village, regional, national, etc.). Multinational companies such as Buhler and Satake also have a presence in China and contribute to availability of high-end sophisticated milling and fortification equipment and facility design.
- When introducing fortified rice in China, it may be best to start with the largest mills for better cost and quality control.

Acknowledgments

We wish to extend our sincere appreciation to Ms. Ying, Professors Huo, and Jin and all stakeholders who provided their time, expertise, and information to the team. We also thank Ying Ching, DSM, Professor Huo Junsheng, China CDC; and Prof. Z. Jin, Southern Yangtze University for organizing the visits.

References

- Chen, Junshi and Huiyun Wu. 1998. Fortification of salt with iodine. *Food and Nutrition Bulletin* vol 19 no. 2 The United Nations University Press. Tokyo, Japan. Accessed at: <http://www.unu.edu/unupress/food/V192e/>
- Gleason, G.R. 2005. Current International Practices and Recommendations on Wheat Flour Fortification in China. UNICEF consultant. Powerpoint presentation. Accessed at: www.pndc.gov.cn/.../Flour%20fortificatgion%20-%20global%20-%20China%20adapted%20by%20GG%20from%20Ranum.ppt
- ILSI China. 2004. The Nutrition and Health Status of the Chinese People. ILSI China Focal Point Newsletter, No. 21. Beijing, China. Accessed at: <http://china.ilsi.org/NR/rdonlyres/9A69B992-5BD0-4026-9395-DC41DE5505D4/0/200421.pdf>
- ILSI China. 2007. Improving Micronutrients through Food Fortification in China. Institute of Nutrition and Food Hygiene, Chinese Academy of Preventative Medicine, Beijing China. Accessed at: <http://china.ilsi.org/FoodFortificatin.htm>
- PATH. 2007a. Path's Ultra Rice® Project. Washington, DC. November, 2007. Accessed at: http://www.path.org/files/MCHN_ultrarice_leaflet.pdf
- PATH. 2007b. Introduction of Fortified Rice using the Ultra Rice® technology: Frequently Asked Questions. September, 2007. Washington, DC. Accessed at: http://www.path.org/files/MCHN_ultrarice_faq.pdf

Table 1. Economic analysis of extruded rice-premix in China (based on production of 1,500 tons per year)

	DSM/Buhler of COFCO		PATH²⁶	
<u>Capital Costs</u>				
Hammer mills	100,000		100,000	
Mixer	260,000		200,000	
Extruders	2,500,000		2,000,000	
Conveyors and dryers	520,000		220,000	
Total Equipment	\$	3,380,000	\$	2,520,000
Building	500,000		350,000	
Total Capital	\$	3,880,000	\$	2,870,000
	DSM/Buhler of COFCO		PATH	
Dilution rice-premix: fortified rice	1:100		1:100	
Micronutrient mix (2% for rice-premix 1:100)	60 kg		60 kg	
Amount rice (MT)	1,440		1,440	
<u>Annual Costs</u>				
Capital ²⁷	\$	194,000	\$	143,500
Interest ²⁸	\$	155,200	\$	228,300
Labor (30x\$12/day @300 days)	108,000		108,000	
Electricity	75,000		75,000	
Fuel	100,000		100,000	
Water	20,000		20,000	
Repairs	77,600		50,000	
Packaging \$0.0667/50 kg bags	2,000		2,000	
Management & QA	100,000		100,000	
Rice \$300/MT	441,000		441,000	
Fortificant mix \$15/kg ²⁹	450,000		450,000	
Total annual costs	1,722,800		1,574,300	
Cost per kilogram rice-premix	\$1.15		\$1.05	

²⁶ No PATH facilities were visited nor are there any facilities in operation in China to the best of our knowledge. The figures of this table are from a similar private operation in Costa Rica, and they are presented for comparison purposes only.

²⁷ Assumes 20 years of useful life.

²⁸ Assumes that the average cost of financing over the 20-year period is 4% of the total capital value.

²⁹ Fortificant mix containing vitamin A would cost US\$20/kg.

Notes:

- a. Equipment costs from on-site visit to Wuxi NutriRice and COFCO
- b. Labor and management/QA costs from:
[http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower\(labor\).htm](http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower(labor).htm)
- c. Electricity costs from:
http://www.gpoba.org/docs/OBApproaches_Philippines_SPUG.pdf

Table 2. Economic analysis of fortified-rice in China (based on production of 300,000 MT/year)

	DSM/Buhler or COFCO		PATH	
Dilution				
Rice-premix : fortified rice	1:100		1:100	
Amount of premix (MT)	3,000		3,000	
Price of rice-premix (\$/kg) ³⁰	\$1.72		\$1.52	
Number of mills (2,500 MT/month)	10		10	
<u>Capital Cost</u>				
Feeder/blender (4/mill x \$5,000)	\$	200,000	\$	200,000
<u>Annual Costs</u>				
Capital ³¹	\$	10,000	\$	10,000
Interest ³²		<u>8,000</u>		<u>8,000</u>
		\$ 18,000		\$ 18,000
Rice Premix		5,160,000		4,560,000
Electricity/ maintenance (\$15,000/mill)		150,000		150,000
Labor/Admo./QC (\$40,000/mill)		400,000		400,000
Total costs		<u>5,728,000</u>		<u>5,128,000</u>
Cost per metric ton fortified rice		\$19.09		\$17.09

³⁰ These prices are about 50% larger than the estimated production costs.

³¹ Assumes 20 years of useful life.

³² Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Annex 3

Rice Fortification in the Philippines by Eric J. Wailes and Tung-Ching Lee

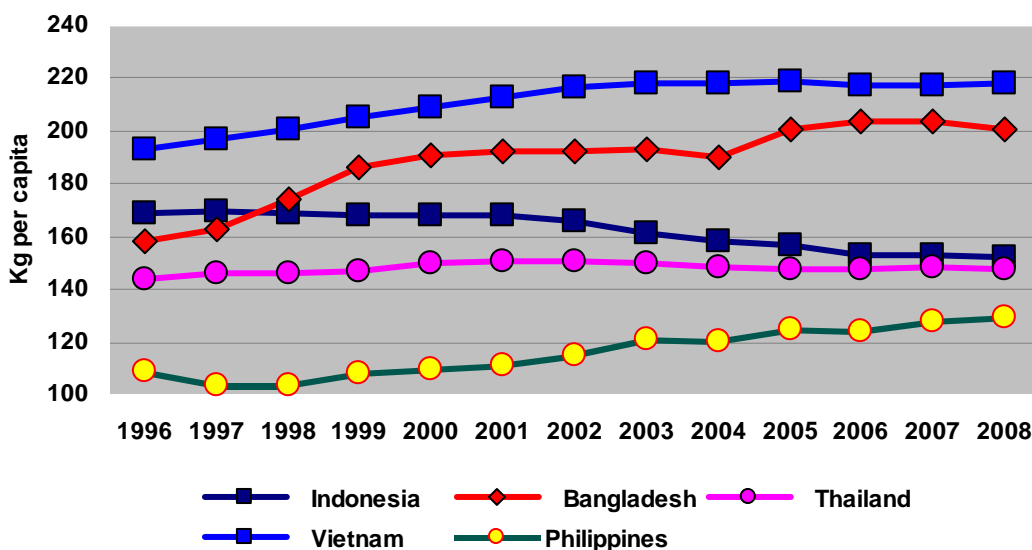
This report is based on stakeholder meetings to assess the status of rice fortification that were held in the Philippines by two consultants of the Institute of Food Technologists from June 12-18, 2007.

Rice Availability and Consumption in the Philippines

Rice is the primary staple food for 93 percent of households in the Philippines (FNRI, 2003). According to the FAO food balance tables, in 2003 rice accounted for 44 percent of the calories consumed on a per capita basis and for 33 percent of the protein consumed. Unlike other Asian countries where average per capita consumption has been level or even decreasing, per capita rice consumption in the Philippines increased from 109 kg/year in 1996 to about 128 kg/year in 2007 (Figure 1). The annual demand for rice in the Philippines is estimated at 11,600,000 metric tons to supply the needs of 91 million persons. Rice is purchased by consumers from retailers primarily in unpackaged bulk bins. The retail rice price in 2007 ranged from US\$0.42 to US\$0.60 based on quality factors.

The supply chain of retail rice deliveries to urban markets involves transportation by small trucks to retail shops. Typical preparation of rice by Filipino households involves rinsing twice before cooking. Washing may result in a substantial loss of micronutrients in rice fortified using the coating methodology.

Figure 1. Per capita rice consumption in the Philippines and selected Asian countries³³



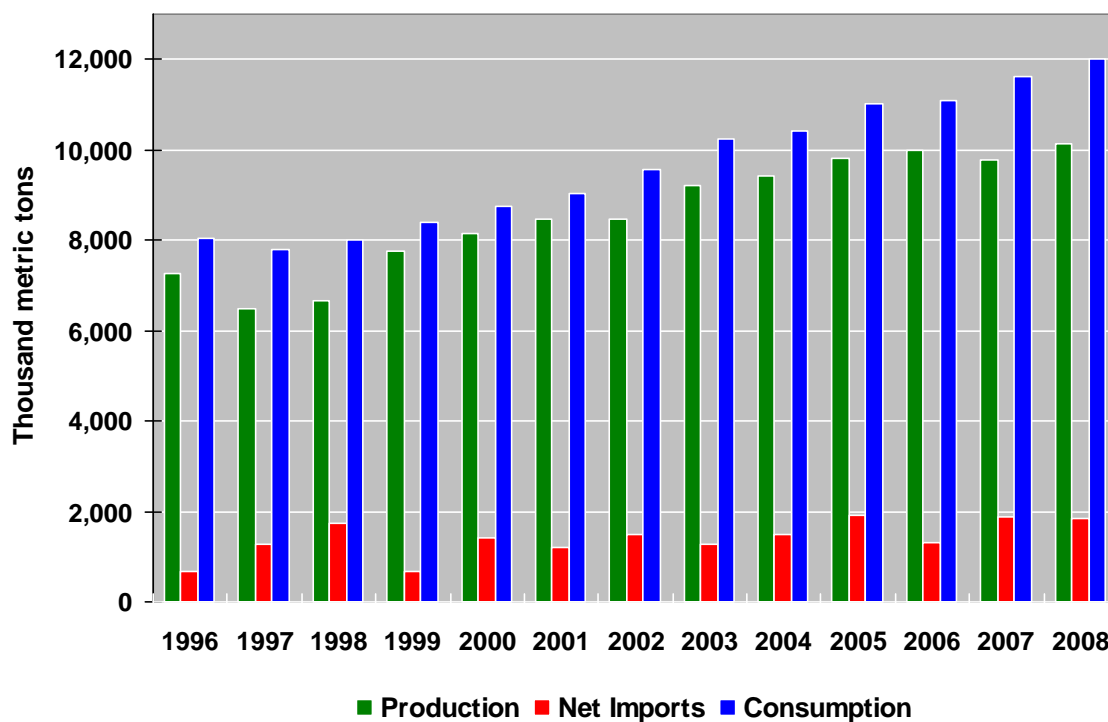
³³ Source: Historical data from USDA, Foreign Agriculture Service, Production, Supply and Distribution online database; projections from Arkansas Global Rice Model

Rice Production and Milling Structure

While rice production in the Philippines has increased, primarily due to higher yields per hectare, it has not kept pace with growth in consumption. Rice imports account for 10 to 20 percent of national consumption. Consequently, the Philippines is a significant global rice importer (Figure 2). As rice is produced on most of the more than 7,100 islands of the Philippines, much of the production and consumption is local. This means that there are many (over 10,000) rice mills in the country, with fewer than 1,000 considered large mills. A large mill in the Philippines would typically have a rated capacity of more than 3 tons per hour (or about 500 to 1,000 MT/month), with the largest having a capacity of 10 tons per hour (or approximately 2,000 to 3,000 MT/month). Small and medium mills found in rural communities used for service or custom milling for farmers and village retail stores have a rated capacity of 0.5 to 3 tons per hour (i.e. 100-500 MT/month or less).

Viet Nam is the dominant supplier of rice imports to the Philippines; however, Thailand and the United States are also important suppliers. Imports are subject to a tariff rate quota. The in-quota tariff rate is 50 percent.

Figure 2. Production, consumption, ending stocks and net rice trade, Philippines³⁴



³⁴ Source: Historical data from USDA, Foreign Agriculture Service, Production, Supply and Distribution online database; projections from Arkansas Global Rice Model

Rice Fortification in the Philippines

Efforts to introduce rice fortification in the Philippines started in 1948 based on an efficacy study that found that rice fortified with Vitamin B-1 reduced beriberi (Salcedo et al., 1950, Williams, 1953). The success of this trial resulted in a law in the early 1950s requiring mandatory fortification, but implementation of the law has not been well documented. In the late 1950s, rice millers and farmers complained that the fortification program was being used to monitor their production and taxable income. Political pressure resulted in the discontinuation of funding of the program by the Philippine Congress (Florentino and Pedro, 1998).

In the 1980s the Food and Nutrition Research Institute (FNRI) initiated a series of studies on a coating technology to fortify rice. A field trial in Gen. Natividad Nueva Ecija conducted in 1993 found a significant reduction in the prevalence of anemia among children who consumed iron-fortified rice (from 88.8 percent at baseline to 73.5 after 6 months of consumption of iron-fortified rice). In subsequent years, further studies of the efficacy and bioavailability of the coating technology using ferrous sulfate iron showed its ability to reduce anemia (Florentino and Pedro, 1998).

The results from the efficacy trials led to passage of Republic Act 8976 in 2000. This act included mandatory fortification of rice with iron. A minimum level of fortification required by the law was set at 60 mg iron/kg, using ferrous sulfate. To date, implementation of mandatory rice fortification has not been achieved. The reasons for the delay are discussed below in the section on strengths and weaknesses of the rice fortification program.

In addition to RA 8976, the rice fortification program in the Philippines depends on several institutions, such as the National Food Authority (NFA). NFA is a quasi-governmental organization with the responsibility to stabilize food grain supply and prices at both the farm and consumer levels and to maintain food security in times and places of calamity and emergency. NFA was reconstituted out of the National Grains Authority through Presidential Decree No. 1770 on January 14, 1981. NFA is the single largest rice miller and rice supplier in the Philippine market. NFA, with approximately 75 rice mills throughout the country, has played a leading role in the effort to implement the rice fortification program. Currently, it mills and distributes approximately 15 percent of all rice consumed in the Philippines but only an estimated 15 percent to 25 percent of this rice is currently fortified (i.e. 2-4 percent of the national consumption).

Technological Capabilities - Current State

The Philippines employs the two major techniques for rice grain fortification: hot extrusion and coating. In both cases, the rate of addition of the iron-rice premix (IRP) to retail rice is 1:200; i.e., 5 kilograms of IRP to produce one thousand kilograms (metric ton) of iron-fortified rice (IFR).

FNRI transferred its coating technology to the National Food Authority, which then produced fortified rice for a school feeding program and a rice subsidy project. NFA pursued development of technologies for production of IRP and IFR using its existing rice processing infrastructure. It also tested the feasibility of imported technologies such as ULTRA rice (extruded-rice premix) from PATH, and coated-rice premix from Wright. Ultimately, it appears that NFA did not adopt

the FNRI coating technology but has to date imported the Wright premix through Vietnamese exporters. The reasons for this choice were not explained.

To attain the standard of 60 mg iron from ferrous sulfate per kilogram of iron-fortified rice, 188 grams of ferrous sulfate should be added per metric ton of IFR, a dilution of 1:5,319. This amount of ferrous sulfate is equivalent to 3.8 percent of ferrous sulfate in the IRP ($5319/200 = 26.6$ dilution factor; $1/26.6 \times 100 = 3.8\%$). The rice-premix should contain 12 grams of iron per kilogram.

Hot Extrusion: Superlative Snacks Incorporated

Superlative Snacks is a small family company that has produced products for the snack market, primarily in the Manila metropolitan area. The firm manufactures puffed rice and sells it as an ingredient for cereals and confectionary products. Superlative Snacks installed and operates the prototype rice extrusion equipment with guidance from FNRI. The company's equipment includes a hammermill to produce the rice flour from broken rice, a mixing drum to add iron fortificant to the rice flour, a single screw extruder to reformulate IFR kernels, and drying bins.

The Superlative Snacks product uses ferrous sulfate to manufacture premix with an iron content of 12 g/kg, and is batch processed with a capacity of about 1,000 kg/day (i.e. 320 MT/year). The suggested dilution ratio of this premix over retail rice is 1:200.

Superlative Snacks has a supply contract with Goldilucks Corporation, a bakery and fast food chain, to serve only the fortified rice. Their product is available currently in 50 fast food outlets in the Manila metropolitan area.

Extruded rice has an off white color and is distinguishable upon close inspection.

Agar-base Coating: CLG Health Food Products coated rice

CLG Health Food Products is located outside of General Santos City, Mindanao. The firm has a basic plant operation with mixing bin, horizontal blender/dryer, and conditioner. The coating substance is a combination of ferrous sulfate and agar and other ingredients, in a proportion 1:1 (the added layer is about 8 percent of the weight in the final product). The layer of iron/agar has very low sticking properties to the surface of the rice grain, and the iron/agar coat is easily detached from the rice grain surface. The technical challenge for the resulting product is under-coating mainly due to use of an insufficient amount of the fortificant (ferrous sulfate). The product is intended to be blended at a dilution rate of 1:200.

The premix has a grayish color with dust and a strong taste of ferrous sulfate. There is also a problem of uneven distribution of the premix in the blended fortified rice product.

CLG and Grains Fortificant Marketing/Second Wind Marketing, a marketing group based in Davao City and General Santos City, are working on marketing plans to distribute and promote "colored" rice for the new generation of rice consumers. The reason for the marketing campaign is to gain acceptance of the clearly noticeable different color of the coated rice when mixed with the retail rice. The marketers believe that colored rice will be attractive to young people. CLG and the Grains Fortificant Marketing/Second Wind Marketing group are also developing IRP packets for households to add to conventional rice at a rate of 1:200 to 1, 2, 10 kg bags. The marketing group is also considering providing rice mills with a blending machine that attaches to the polishing process to stimulate more rice millers to purchase this iron rice premix.

Imported Coated Rice Premix: Wright Enrichment Inc. Louisiana-USA

Fortified premix manufactured using the coated technology by the Wright Enrichment Inc. of Crowley, Louisiana, USA is imported from Viet Nam by the NFA and Mr. Joji Co rice milling company. This is the largest supply chain in the country, and is handled by the NFA. An estimated volume of 250 metric tons of the rice premix was imported in 2006 to fortify 50,000 MT of retail rice. In addition, 300,000 MT of already iron fortified-rice was imported from Viet Nam.

Mr. Co is also commercially marketing IFR utilizing the coated Wright fortified rice-premix. The three commercial brands of fortified rice—Matador, Ranger and Warrior—are currently being sold by retail markets in the northern Luzon area and Manila. The volume is limited to date.

This iron rice-premix is diluted 1:200 over the retail rice. Field trials of the NFA coated fortified rice found that the iron content of the premix was 7.2 g/kg (a dilution 1:200 of this IRP would add 36 mg/kg of iron to the retail rice). While the uncooked blended rice has 72 mg/kg iron, the cooked blended rice has 12 mg/kg. Although these two values are not based on the same dry weight, the big difference suggests that there are large losses of iron during washing and cooking of the rice.

During the team's visit, the NFA blending facility located outside of Manila, rice driers were being used as blenders, which was said to be a temporary approach. In the longer term, it is expected that mills in the Philippines will have feeder/blender/mixer equipment designed specifically for this purpose and attached to the conventional milling equipment.

Currently, the iron-fortified blended rice primarily goes to schools in 50 kg bags.

In our opinion, while ferrous sulfate has the attractive feature of high bioavailability, the coated iron fortified-rice has significant quality and acceptability problems as a result of its golden color, off-taste, and loss of iron during the rinse-wash preparation for cooking.

Cost Associated with Fortification

The owners of Superlative Snacks (extruded rice) estimated that the cost of fortifying rice with the premix is about PhP 1,000/MT (i.e. US\$ 25/MT). This cost estimation may include advertising, but in any case, it seems that the price of the rice-premix is high, probably ranging from US\$2-4/kg, considering that 80 percent of the cost is due to the IRP. This price is high compared with the estimated cost of US\$ 1.03, calculated from the cost structure of the Superlative Snacks Company presented in Table 1. The difference may be attributable to the small plant capacity of this factory as well as the rice mills where the IRP is being used. The total capital investment for Superlative Snacks is estimated to be approximately \$585,000.

Equipment of the CLG Company is very simple, and the cost is around US\$20,000. However, the total capital investment is approximately US\$150,000, when the cost of the building is added (Table 2). As with Superlative Snacks, the reported fortification cost using the coated-IRP was PhP 1,000/MT (i.e. US\$25/MT). The difference between the estimated cost (US\$0.95) and the probable price of this product (US\$2-4/kg) was also large.

NFA's import of iron-fortified premix rice in 2006 was reported to cost US \$3/kg. However, the NFA indicated that the price dropped to US\$2/kg in 2007.³⁵ This latter figure provides confidence to our calculations (Tables 1 and 2), because the imported-premix should also add the cost of overseas delivery and storage.

The cost structure for the iron fortified-rice produced by the NFA is difficult to determine. Production of blended iron-fortified rice is based upon makeshift use of drying equipment and feeder/blender/mixer equipment attached to regular rice polishing equipment used to blend the premix. The primary cost of this process, in addition to the imported rice-premix, is the feeder/blender/dryer machine. NFA indicated that the cost of the premix and blending adds PhP 2,000/MT to the cost of their rice (i.e. US\$50/MT). It seems that this cost estimation is highly inflated, judging by the calculated costs that are presented in Table 3. Assuming a price of US\$2/kg of the iron rice-premix, the overall cost of rice fortification in the Philippines should be around US\$11.00/MT.

Assessment of Strengths and Weakness of Current Program in the Philippines

The key strength of the current rice fortification program in the Philippines is the interest of the stakeholders in a program of this type. The Food and Nutrition Research Institute-Dept. of Science and Technology has displayed some capacity to support food fortification. There are also a myriad number of agencies involved including Food Development Center of the National Food Authority, DOFH, FDA, and many universities. The unique status of the NFA (National Food Authority) is its responsibility to stabilize food grain supply and price, at both farm and consumer levels, and the recognized strength of the program as a social-sponsored project.

The clear weakness of the rice fortification program in the Philippines is lack of capacity/infrastructure to support a mandatory fortification program and little coordination and leadership among stakeholders.

The quality of the fortified rice is problematic. Coated fortified rice, and in some degree the extruded fortified rice, has a distinctive color that makes it easily distinguishable from the unfortified white rice. A change of behavior will be required to gain consumer acceptance of the colored grains. Another major constraint with fortified rice in the Philippines is the traditional process of rinsing (done twice) before cooking, which results in micronutrient losses, especially with the coating technology. The coating technology currently in use deserves a thorough review, not only because the fortified product changes color and taste, but also because the nutrient layer detaches from the rice surface and is lost during washing and cooking.

Although the capital investment of a local premix factory using the extrusion method is approximately four times greater than the investment of a factory using the coating method, the cost and price of the rice premix is similar. The coating method requires additional ingredients to create the sticking layer on the surface of the grain, and these ingredients plus the ferrous sulfate are the two most expensive items in the coating formulation. In conclusion, the extrusion method appears to be preferable in the Philippines.

³⁵ The NFA sent a letter to AED in 2011 informing that this information was incorrect. In the Annex 1 of the letter, the NFA reported that the program pays \$ US 5.40/kg for the Iron Rice Premix, and which is based on 7 years of operations. This price includes transportation and storage costs, as well as importation duties.

The country needs 7,500 metric tons of rice-premix to fortify 1.5 million metric tons of rice, which represents 13 percent of the national demand and the estimated amount handled by the NFA. Regardless of whether the premix is produced by extrusion or by coating, the price is similar. If one assumes a price of US\$2/kg; then the annual expenditure on rice-premix would be US\$15 million. This cost is about 91 percent of the overall cost of the program. If the program is administrated properly, the additional cost of rice fortification would be in the order of US\$11.00/MT or 1.8-2.6 percent of the current rice price (US\$0.42-0.60/kg). At this rate, rice fortification in the Philippines would cost US\$1.41/year per consumer.

The capital investments to create a self-sufficient program in the Philippines should consider setting up 25 factories to produce the rice premix, each one with a daily capacity of 1 MT, for a total investment of around US\$10-15 million with the extrusion method. Additionally, feeders and, if needed, mixing devices, should be incorporated into the 75 mills administrated by the NFA. Assuming that each one of these mills is going to use two feeder lines, the initial investment is approximately US\$750,000.

A decentralized rice milling industry characterized by a few large mills and many small mills located on more than 7,100 islands creates logistical issues for premix delivery, feeding and mixing, quality control and supervision. Blending is most feasible at large-scale mills, which have the advantage of cost-effectiveness and the capacity for quality assurance and control. The efficiency of this activity is reduced significantly at small scale mills, where many of the most vulnerable population access their food. Supervision and enforcement certainly will be a significant management problem. Therefore, the most feasible strategy for rice fortification in the Philippines seems to be a social program administrated by the NFA.

Finally, it is interesting to note that the team did not see any fortified rice in the marketplace despite the national mandate. The nature of the rice milling industry in the country explains this finding.

General Recommendations

During the team's site visits, we saw various iron-fortified rice products and observed some of the processes (milling extrusion, blending, drying and packaging) using two available major methods (coating and extrusion). We also observed on-site quality control standards and practices (i.e., counting colored kernels in the blended rice). Obviously, the quality of the product varies and improvements for standardization are desirable. However, all of the personnel appeared motivated in their work.

The industry is aware of the need for technical research and development, including product development, process optimization, selection of iron fortificants, and packaging shelf-life extension. In general, extruded iron-fortified rice is better than iron-coated rice in terms of appearance, stability and nutrition retention.

One of the major concerns is the cost of processing equipment (e.g., extrusion machine, coating machine, blending machine, drying machine, and packaging machine) as this ultimately affects the cost of the fortification program. Several machines used on site are imported from Japan and the U.S. at high cost. These types of machines probably could be produced locally in the Philippines or regionally from Taiwan, China, Thailand, and other neighboring countries at much lower prices.

The concept of food fortification for public health purposes needs to be established. Hence, the program must differentiate food fortification for public health interest from food fortification for industry-profit through introduction of branded products aimed to high-end market consumers.

To achieve success, the national fortification program must develop a model to meet business standards. The rice fortification program would benefit greatly from a very detailed economic engineering study to evaluate the capital and operating costs of local premix facilities and the feeder/blending equipment that would be needed.

The promoters of food fortification must inform policy makers about the expected costs and governmental involvement in a program of this magnitude.

References

- Department of Health, Government of the Philippines. The Philippine Food Fortification Program. Accessed at: <http://www2.doh.gov.ph/foodfortification/downloads.htm>
- Food and Agriculture Organization, FAO. 2003. FAO STAT. Food Balance Sheets. At: www.fao.org
- Food and Nutrition Research Institute, FNRI. 2003. Presentation PowerPoint provided during interview on 14 June, 2007. Manila, Philippines.
- Florentino, R.F. and Ma. R.A. Pedro. Update on rice fortification in the Philippines. *Food and Nutrition Bulletin*, Vol. 19, No 2:149-53. 1998 The United Nations University, Tokyo, Japan. Accessed as: <http://www.unu.edu/unupress/food/V192e/begin.htm>
- Salcedo, Jr. J., M.D. Bamba, E.O. Carrasco, G.S. Chan, I. Concepcion, F.R. Jose, J.F de Leon, S.B. Oliveros, C.R. Pascual, L.C. Santiao and R.C. Valenzuela. Artificial Enrichment of White Rice as a Solution to Endemic Beriberi. *J. of Nutrition*, Vol. 42, No. 4, December, 1950.
- Williams, R.R. Philippine Rice Enrichment—When and How? Proceedings of Eighth Pacific Seminar Congress of the Pacific Science Association, 1953. Quezon City.

Table 1. Economic analysis of extruded iron rice-premix for Superlative Snacks (based on production of 300 tons per year)

<u>Capital Costs</u>	
Hammer mills	50,000
Mixer	60,000
Extruders	355,000
Dryers	<u>20,000</u>
Total Equipment	\$ 485,000
Building	<u>100,000</u>
Total Capital	\$ 585,000

Annual Costs

Capital ³⁶	\$	29,250	
Interest ³⁷		<u>23,400</u>	\$ 52,650
Labor (5 x \$7day @ 300 days)			10,500
Management/supervision			10,000
Utilities: Electricity, water, fuel			50,000
Milling			30,000
Repairs			10,700
Packaging 6000 x \$0.05/50 kg bag			300
Rice 290 MT x \$300/MT			87,000
Fortificant mix 11,400 kg x \$5.00/kg			<u>57,000</u>
Total annual costs	\$		<u><u>308,150</u></u>

Total cost per kg: \$1.03.

Notes:

1. Equipment costs from Superlative Snacks and CLG
2. Labor and management/QA costs from:
[http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower\(labor\).htm](http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower(labor).htm)
3. Electricity costs from:
http://www.gpoba.org/docs/OBApproaches_Philippines_SPUG.pdf

³⁶ Assumes 20 years of useful life.

³⁷ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Table 2. Economic analysis of iron rice-premix manufactured by coating method for CLG (based on production of 300 tons per year)

<u>Capital Costs</u>		
Premix container and sprayer		10,000
Screw blender and dryers		7,500
Total Equipment	\$	<u>17,500</u>
Building		<u>125,000</u>
Total Capital	\$	142,500

Annual Costs

Capital ³⁸	\$	7,125	
Interest ³⁹	\$	<u>5,700</u>	\$ 12,825
Labor (2 x \$5day @ 300 days)			3,000
Management/Supervision			3,000
Utilities: Electricity, water, fuel			3,000
Repairs			3,000
Packaging 6000 x \$0.05/50 kg bag			300
Rice 276 MT x \$300/MT			82,800
Agar and other ingredients 12,000 kg x \$ 10 /kg			120,000
Iron mix 11,400 kg x \$5.00/kg			<u>57,000</u>
Total annual costs	\$		<u><u>284,925</u></u>

Total cost per kg: \$0.95.

Notes:

1. Equipment costs from Superlative Snacks and CLG
2. Labor and management/QA costs from:
[http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower\(labor\).htm](http://www.coa.gov.ph/tsolmp/TSOIntra/Manpower(labor).htm)
3. Electricity costs from:
http://www.gpoba.org/docs/OBApproaches_Philippines_SPUG.pdf

³⁸ Assumes 20 years of useful life.

³⁹ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Table 3. Economic analysis of iron fortified-rice by the NFA of the Philippines (based on production of 1,500,000 MT per year)

<u>Capital Cost</u>		
Feeder/blender (75 mills x 2 feeders x \$5,000)	\$	750,000
 <u>Annual Costs</u>		
Capital ⁴⁰	\$	37,500
Interest ⁴¹		<u>30,000</u>
	\$	67,500
Rice premix (7,500 MT x \$2.0/kg)		15,000,000
Labor/Administration/QC (75 mill x \$ 12,000)		900,000
Electricity/maintenance (75 mills x \$6,000)		450,000
Total annual costs	\$	<u><u>16,417,500</u></u>

Note: The cost figures in this table are for a generic coating operation, not for any specific firm.

Total cost per metric ton of fortified rice: \$ 10.95.

⁴⁰ Assumes 20 years of useful life.

⁴¹ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Annex 4

Rice Fortification in Costa Rica by **Sajid Alavi and Gail L. Cramer**

This report is based on stakeholder meetings to assess the status of rice fortification that were held in Costa Rica by two consultants of the Institute of Food Technologists from June 17-20, 2007.

Rice Availability and Consumption

Costa Rica has a population of 4 million. Rice is a staple food and meets about 30 percent of the daily caloric intake of the population. Per capita annual consumption of rice is 55 kg or 121 lb, and hence the total annual consumption of the country is approximately 220,000 metric tons (MT). The country produces two rice crops per year. The major crop is harvested in December and the other from May to July. Domestic production of rice paddy is around 190,000 metric tons. The area under rice cultivation varies widely due to the profitability of sugar cane. Currently, about 55,000 hectares are utilized for rice production in the northern and southern Pacific regions (FAS-USDA, 2004).

Imports of rice are determined by local production and stocks. Roughly 45 percent of the annual consumption of rice is met by imports. Imported rice paddy has increased from 37,000 MT in 1990, to 100,000 MT in the late 1990s, to 180,000 MT in 2007. The rice corporation (CONARROZ) is the sole entity allowed to import rice within the set quota. Millers maintain a two-month stock of rice or about 36,000 MT. Imported rice is received in November, February, and late May to blend with lower quality domestic rice. There is a 35 percent *ad valorem* duty on imported rice and a price-based safeguard of 19 percent plus a \$19 per MT sanitary and quality inspection fee. These levies are used by the government to control imports and maintain a stable domestic rice industry. However, most imports are allowed into the country duty free because the government issues 'shortage decrees' that eliminate these levies.

The average price of rice (90 percent whole, 10 percent broken) at retail stores in Costa Rica was US\$ 0.63 in 2007.

Rice Fortification in Costa Rica

Rice fortification was made compulsory by an executive decree in Costa Rica in 2001, primarily to address deficiencies in folic acid, vitamin B-12, and selenium and associated health problems related to neural tube defects and anemia. Government regulations mandate the following minimum levels (per kg) of micronutrients in rice:

Vitamin B-1	6.0 mg
Niacin	50 mg
Folic acid	1.8 mg
Vitamin B-12	10.0 µg
Vitamin E	15.0 IU

Selenium	105.0 µg
Zinc	19.0 mg

All rice sold in the country has to be labeled with the quantities of the above micronutrients. However, regulatory inspections of rice fortification and milling companies are not carried out, and neither is any certification required for production of fortified rice. Although the government maintains that there is 100 percent compliance with its rice fortification guidelines, according to some anecdotal estimates, 5-20 percent of the rice sold in Costa Rica is either unfortified or fails to meet the minimum mandated levels of micronutrients. However, there are no official figures or references to back any of these claims.

INCIENSA, with a workforce of 150, is the primary government agency responsible for monitoring fortification of rice in Costa Rica. It carries out this task by random sampling of products from the marketplace. The technological and monitoring capabilities of INCIENSA are limited. For example, the standard test for folic acid has not yet been established. However, government surveys indicate that programs for fortification of rice and other products such as sugar, wheat and corn flours, and salt have had a significant impact in reducing deficiencies and improving public health.

Technological Capabilities - Current State

For the purpose of this report, the vitamin/mineral blend will be referred to as *fortificant mix*, the rice grains fortified with the fortificant mix as *rice-premix*, the polished rice packaged at the rice miller as *retail rice*, and the retail rice combined with the rice-premix as *fortified rice*. The accepted fortification practice in Costa Rica is to supplement the retail rice with rice-remix at a ratio of 1:200 during packaging (i.e. 5 kilograms of rice-premix per metric ton of retail rice).

The direct cost of rice fortification is primarily borne by the private sector, which then adds this cost to the product price. Approximately 25 decentralized, medium-sized (about 2000 MT/month, or about 5-10 MT/hour) rice milling facilities operate in the country, adding the rice-premix to retail rice using dosifiers in a ratio of 1:200 before being packaged. A typical rice miller (for example, Arrocería Miramar) could have 5 packaging units for retail rice, each of which has a dosifier attached to it. Rice-premix is added to the dosifier holding bin, which has a capacity of 50 kg. Each dosifier has a delivery rate of approximately 100 g/min. All the rice-premix in Costa Rica is supplied to rice millers by two companies – Vigui and Grupo NTQ. About 50-56 percent of the rice sold in the country is fortified with Vigui’s Vitarroz brand rice and 30-40 percent with Grupo NTQ’s ‘Super Grain’ product. DSM is the micronutrient premix supplier for Vigui, while Fortitech is the supplier for Grupo NTQ.

Vigui and Grupo NTQ employ different technologies for the production of rice grains fortified with micronutrient premixes (rice-premix). Vigui fortifies fabricated grains formed by extrusion, and Grupo NTO fortifies through wax coating. These technologies are described in detail below.

Cold Extrusion – ‘the Vigui Way’

Vigui is a sub-contractor to DSM for production of fortified extruded rice (Vitarroz brand) for the Costa Rica market. Vigui produces 600-650 MT of rice-premix per year at a daily capacity of roughly 2,000 kg in single, 8 hour shifts per day. The main extrusion equipment is operated only 1 hour per shift. A total of 100 people are employed at the Vigui plant, and 11 of them are directly involved in the production of extruded fortified rice. The fortificant mix is sourced from

DSM locations primarily in Mexico at no cost to Vigui; DSM also manufactures fortificant mixes at locations in Brazil and Colombia. Extruded rice is based on flour from broken rice. The broken rice is purchased primarily from a Costa Rican rice milling company, Grupo Arrocería Miramar, which is also a customer for Vigui's fortified rice.

The process flow for the fortified extruded rice (Vitarroz) is shown in Figure 1 at the end of this report. Broken rice is first milled to flour using hammer mills. The flour is mixed with 2 percent of the fortificant mix, and water is added to adjust the overall moisture to about 35 percent (wet basis) in batch mixers. The flour is then transferred to a low shear pasta press (Pavan, Italy) that reform the rice flour into rice-like kernels using a specially designed screw and die, and a continuously acting rotational knife. The re-fabricated rice-premix grains are then pre-dried in a perforated belt (9 passes), continuous drying system (imported from Italy) using hot air at 70°C for 2-2.5 hours. The partially dried rice-premix is then stacked in trays and placed in conditioning chambers for 8 hours for final drying at 60-70°C. The dried rice-premix is transferred to a concrete storage silo before bagging and storage in a warehouse.

According to Vigui, their rice-premix has two main advantages over the coated rice-premix produced by its competitor. First, the micronutrients are embedded inside the rice grain, so they are not removed during washing of rice by consumers, which can be a big problem, especially in Costa Rica where the general practice is to wash rice three times prior to cooking. Second, the rice-premix using extrusion does not have the bad odors associated with coated rice. One negative aspect of the extrusion process is that it generates mechanical shear and also heat, which can damage the micronutrients. According to Vigui, the additional level of the premix ensures there is an 'overage' of 40 percent for folic acid, vitamin E, vitamin B-1, and vitamin B-12, 20 percent for niacin, and 5 percent for minerals. This takes care of any destruction of micronutrients during the extrusion process. Quality control tests such as equipment validation, nutrient analysis, and stability testing for the extruded rice-premix are performed regularly by DSM.

The micronutrient content of this rice-premix appears below:

Micronutrient content of Vigui rice premix

Micronutrient	Source (Fortificant)	Amount⁴²
Vitamin B-1	Thiamine hydrochloride or thiamine mononitrate in crystalline powder form	1.7 g/kg
Niacin	Nicotinic acid or nicotinamide in powder form	12.0 g/kg
Folic Acid	Folic acid in pure crystalline powder form	0.50 g/kg
Vitamin B-12	Cyanocobalamin in crystalline powder form	0.003 g/kg
Vitamin E	Tocopherol or tocopheryl acetate in powder form	4200 IU/kg
Selenium	Selenomethionine, sodium selenite or sodium selenate	0.022 g/kg
Zinc	Zinc oxide	4.0 g/kg

⁴² The amount includes the reported overages.

The Vigui rice-premix is slightly yellowish in color with no apparent odor. On careful observation, it is possible to differentiate the rice-premix from the retail rice based on color. The product is very stable with a claimed shelf-life of 8-10 months.

Coating – ‘the Grupo NTQ Way’

Food fortification is only 5 percent of the total business of Grupo NTQ, which is primarily a manufacturer of 150 different food formulations, such as premixes for cup cakes and cookies and dehydrated nutritional beverages. Approximately 400 MT of rice-premix per year (Super Grain brand), at a daily rate of 1,250 kg/day, is produced by Grupo NTQ through its subsidiary Kuruba Industries, based on a proprietary and patented batch coating technology. The fortificant mix is purchased from Fortitech Inc. (Schenectady, NY). while the rice to be fortified is supplied cost-free by rice millers.

The coating process employs a special mixture called Kuruwax, which is made up of palm oil-based wax, gums, and an emulsifier. The mixture was developed and is now produced by Grupo NTQ. The patent application for this coating mixture is underway. Two solutions are prepared, one containing only Kuruwax and the other containing Kuruwax and fortificant mix in a 1:1 ratio, by dissolving in water at 85°C. A special batch coating drum, modified from drying and cleaning drums used in the milling industry, is then used for applying these solutions onto the surface of rice grains in a five-step (or five-layer) process, with each step involving a coating of the Kuruwax solution followed by a coating of the Kuruwax – premix solution. The coated rice is simultaneously dried in the drum using hot air. The final moisture content of the coated rice is 10 percent (wet basis). The capacity of the coating drum is 500 kg/batch, and it takes 1 hr to complete a batch.

Grupo NTQ cites three advantages of their process: 1) simplicity and low cost, 2) the ability to retain the micronutrients even after multiple washing of rice (only 4 percent losses in standard tests), and 3) almost no destruction of micronutrients during the fortification process. Quality control tests such as nutrient analysis and stability testing for the fortified rice are performed on a regular basis through Covance, a U.S.-based company.

The micronutrient content of this rice-premix appears below:

Micronutrient content of Grupo NTQ rice-premix

Micronutrient	Source (Fortificant)	Amount
Vitamin B-1	Thiamine hydrochloride or thiamine mononitrate	1.2 g/kg
Niacin	Nicotinic acid, nicotinamide or inositol hexanicotinate.	10.0 g/kg
Folic Acid	Folic acid or folinic acid	0.36 g/kg
Vitamin B-12	Cyanocobalamin or methylcobalamin	0.002 g/kg
Vitamin E	Alpha-tocopherol	3000 IU/kg
Selenium	Sodium selenite or selenomethionine	0.021 g/kg
Zinc	Zinc oxide	3.8 g/kg

The NTQ rice-premix is slightly yellowish in color with some vitamin-like odor. It is possible to differentiate the rice-premix from the retail rice based on color. The product is very stable with a claimed shelf-life of 6-8 months.

Costs Associated with Fortification

Almost all rice sold in Costa Rican stores is fortified. Only two rice-premix manufacturers are able to produce enough rice-premix to provide the government recommended nutrient requirements for the entire population of Costa Rica. The two manufacturers produce 1,160 MT/year of rice-premix, which is enough to fortify 232,000 MT of retail rice.

The fortificant mix is obtained from DSM Nutritional Products in Mexico and Fortitech in the USA by Vigui and Grupo-NTW, respectively. The fortificant mix is imported in 25 kg boxes containing 5 kg bags. The cost of the fortificant mix varies from \$15/kg to \$30/kg depending on the supplier.

The cost of producing extruded rice-premix is about US\$1.44/kg (Table 1) whereas the cost of producing coated rice-premix is US\$0.99/kg (Table 2). The actual selling price of the enriched rice to millers is \$1.69/kg and \$1.25/kg, for extruded and coated products, respectively. Either method could be used to produce the amount needed for the entire country of Costa Rica. These fortification operations are very small, and very little added investment is needed in the country as a whole to accomplish fortification. Given the present technology, the capability for blending rice-premix into retail rice could be added easily to any rice mill. A typical dosifier costs \$4,000, so the total equipment costs for 5 units would be \$20,000. Assuming a 20-year operational life, the depreciation costs would be \$1,000/year for that mill.

The average total cost of rice fortification in Costa Rica is about US\$8-10/MT (Table 3). Rice-premix represents the largest cost item (78 percent to 84 percent), while feeders/blender and other inputs have an annual overall cost of approximately US\$386,000 for the whole country, that is about US\$15,000/year per mill. Therefore, the total cost (without considering the cost of supervision and monitoring by the government) of the rice fortification program in Costa Rica for 4 million people is approximately US\$1.8 to US\$2.2 million dollars per year, or \$0.44 to US\$0.55/year per person.

Strengths and Weakness of Current Program

The strengths of the current rice fortification program in Costa Rica include its favorable economics and clearly discernable positive health impact. The fortification cost per package of rice is so low and consumer demand is so inelastic that most of the increased cost to fortify rice is passed on to the consumers. In a kilogram of rice, the cost is so minor that few consumers would notice the small price increase, which is approximately 1.3-1.6 percent of the current price. Therefore, the cost to fortify rice has a very small impact on rice consumption in Costa Rica.

The weaknesses of the current program include both technological and regulatory aspects. The biggest bottle-neck to the production of fortified rice by extrusion, which comprises more than 50 percent of the market, is the slow drying process (steps 6 and 7 in the process flow, Figure 1)

that takes about 8.5 hours. Another drawback to the overall rice fortification program is the lack of a strict regulatory and testing mechanism due to both technological and administrative shortcomings. One of the main constituents of the micronutrient premix is folic acid, but the governmental regulatory authority INCIENSA lacks the capability for testing its fortification levels. Moreover, there are no regulatory inspections of fortification and milling facilities to ensure that proper practices are being followed. According to one estimate, up to 20 percent of the rice in Costa Rica is not being fortified, and the rice that is being fortified does not meet mandated levels.

Summary and Recommendations

To summarize, Costa Rica's current fortification program is likely to succeed because of the low economic costs (US\$8-10/ MT). In 2007 the total yearly cost of rice fortification was approximately US\$2.0 million or US\$0.50 per person per year.

Technological and economic changes could streamline Costa Rica's rice fortification program. The drying process for extruded fortified rice is very slow and can be made more efficient. Vigui actually plans to replace the current drying steps with a faster automatic drying step that will take only 30 minutes. This automatic dryer is being designed by Vigui, and its incorporation will lead to significant increases in efficiency and cost savings.

Better monitoring and regulation on the part of the government is needed. The government plans to expand the role of INCIENSA in the coming year to become the overall national disease control and health monitoring agency (a sort of combination of the U.S. Centers for Disease Control and the National Institute of Health). With regards to its regulatory role, it is recommended that the INCIENSA acquire folic acid testing technology, and start testing for this important micronutrient as part of its ongoing program. Currently fortification companies voluntarily conduct various quality control tests; however, to ensure compliance, the team recommends that the government start on-site inspection of fortification companies and rice millers and initiate a certification program.

References

Foreign Agriculture Services, US Department of Agriculture. Grain Report, CS-4016 Foreign Agricultural Service, 12/16/2004

Spectrum Chemical supplier catalog

<http://www.spectrumchemical.com/retail/product.asp?catalog%5Fname=Chemicals&product%5Fid=5759525>

Science Lab.com <http://www.epoxy-paint.net/page/S/PVAR/10429/SLV1087>

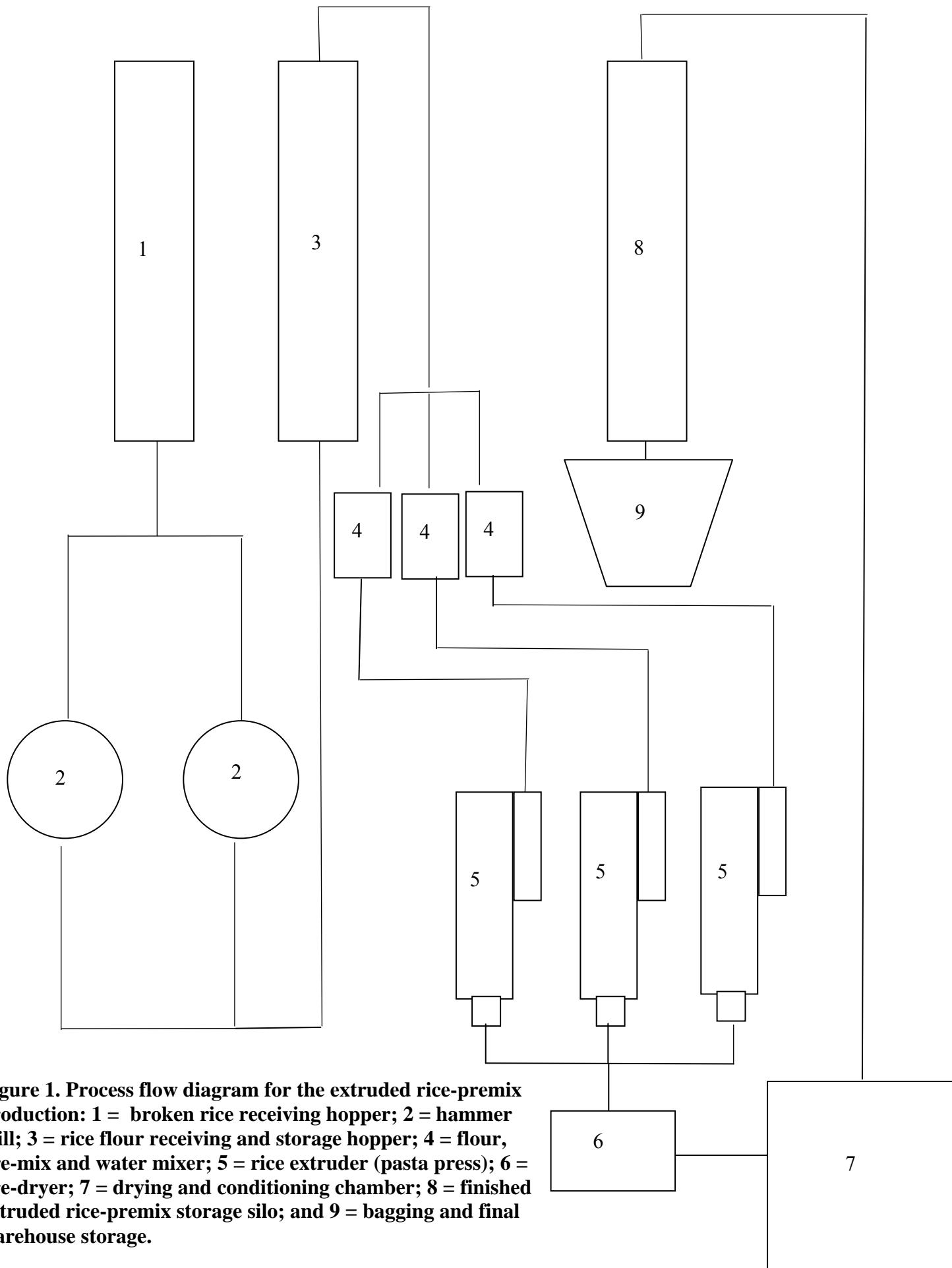


Figure 1. Process flow diagram for the extruded rice-premix production: 1 = broken rice receiving hopper; 2 = hammer mill; 3 = rice flour receiving and storage hopper; 4 = flour, pre-mix and water mixer; 5 = rice extruder (pasta press); 6 = pre-dryer; 7 = drying and conditioning chamber; 8 = finished extruded rice-premix storage silo; and 9 = bagging and final warehouse storage.

Table 1. Economic analysis of rice-premix manufactured by extrusion method in Costa Rica (based on production of 730 tons per year)

<u>Capital Costs</u>		
Silos	\$	90,000
Hammer mills		100,000
Mixers		60,000
Extruders (pasta presses)		450,000
Dryers		20,000
Total Equipment	\$	<u>720,000</u>
Building		<u>50,000</u>
Total Capital	\$	770,000
 <u>Annual Costs</u>		
Capital ⁴³	\$	38,500
Interest ⁴⁴		<u>30,800</u>
	\$	69,300
Labor		52,800
Electricity		36,000
Fuel		60,000
Water		12,000
Repairs		10,000
Rice		189,800
Milling		73,000
Packaging		2,414
Wooden pallets		12,072
Management		92,414
Fortificant mix		<u>438,000</u>
Total annual costs	\$	<u><u>1,047,800</u></u>

Note: The cost figures in this table are for a generic extrusion operation, not for any specific firm.

Total cost per kg: \$1.44.

⁴³ Assumes 20 years of useful life

⁴⁴ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Table 2. Economic analysis of rice-premix manufactured by coating method in Costa Rica (based on production of 430 tons per year)

<u>Capital Cost</u>	
Drums and sprayer	\$ 300,000
<u>Annual Costs</u>	
	\$
Capital ⁴⁵	15,000
Interest ⁴⁶	<u>12,000</u>
	\$ 27,000
Administration	18,000
Labor	26,957
Electricity	3,000
Water	600
Repairs	3,600
Wax	4,000
Fortificant mix	154,800
Broken rice (.26/kg)	52,000
Rice Grain (.63/kg)	126,000
Packaging	1,500
Wooden pallets	<u>7,200</u>
Total annual costs	\$ <u><u>424,657</u></u>

Note: The cost figures in this table are for a generic coating operation, not for any specific firm.

Total cost per kg: \$ 0.99.

⁴⁵ Assumes 20 years of useful life

⁴⁶ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Table 3. Economic analysis of rice fortification (based on production of 220,000 tons per year) (variable cost) in Costa Rica

<u>Capital Cost</u>		
Feeder (4 x 25 mills x \$4,000)	\$	400,000
<u>Annual Costs</u>		
Capital ⁴⁷	\$	20,000
Interest ⁴⁸	<u>16,000</u>	\$ 36,000
Rice premix (1,100 MT x \$1.25-1.69/kg)		1,375,000 – 1,859,000
Labor/Administration/QC (25 mill x \$ 12,000)		300,000
Electricity/maintenance n(25 x \$2,000)		50,000
Total annual costs	\$	<u><u>1,761,000 – 2,209,000</u></u>

Notes:

- 1) The cost figures in this table are for a generic coating operation, not for any specific firm.
- 2) The rice premix is purchased and not produced by the firm

**Total cost per metric ton of fortified rice: \$ 8.00 – 10.04.
(using coated or extruded rice-premixes, respectively)**

⁴⁷ Assumes 20 years of useful life

⁴⁸ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

Annex 5

Rice Fortification in the United States of America by Sajid Alavi and Gail L. Cramer

This report is based on stakeholder meetings to assess the status of rice fortification that were held in the United States by two consultants of the Institute of Food Technologists on November 13, 2007; December 4, 2007 and December 10-12, 2007.

Rice Availability and Consumption in the United States

The total population of the United States is 300 million. Annual per capita consumption of milled rice in the U.S. is around 14 kg/year (or 30 lbs/year) and is expected to remain at this level. The annual national availability of milled rice is around 4,200,000 M.T. (1 metric ton = 1,000 kg). In comparison, consumption of wheat is 91 kg/year (or 200 lbs/year) per capita, and consumption of coarse grain (corn, oats, barley, and sorghum) is 363 kg/year (or 795 lbs/year). Given the relatively low consumption of rice compared to other grains, consumption of enriched rice in the U.S. has a small impact on the nutrition of the population.

Rice Production and Milling Structure

Only 2.8 million acres of rice are planted out of 340 million acres of available farm land. Six states produce most of the U.S. rice. Arkansas is the major producer with half of the acreage. Other producers are California, Louisiana, Missouri, Mississippi, and Texas. In the U.S., the rice industry has few major millers (roughly 20-30) and exporters, and they are capable of handling any fortification program. These operations can produce more than 50 metric tons of milled rice per hour.

Total rough rice production in the country is 194 million hundred weight (cwt) or 8,800 million metric tons, and nearly half of that amount is dedicated to export to Europe, Asia, and Central America⁴⁹.

In 2006-07 the average farm price for rough rice was \$ 0.097 or 9.7 cents per lb and is expected to reach 11 cents per lb in 2007-08. The consumer price of retail rice is US\$0.50-1.00/kg.

Rice Fortification in the U.S.

Rice naturally contains thiamin, niacin, and iron. However, during the milling process, the quantities of these micronutrients are reduced. Therefore, to bring the nutritional level of white rice to the brown rice equivalent, rice is enriched with thiamin, niacin, and iron. Over 70 percent of the white rice consumed in the U.S. is enriched or fortified⁵⁰.

⁴⁹ All data for rice are estimated numbers for 2006-07 from *Rice Year Book 2007* published by the Economic Research Service of the U.S.D.A.

⁵⁰ Goya Foods Basics. <http://www.goya.com/english/nutrition/basics_rice.html>

Rice fortification is not mandatory in the U.S., except for six states (Arizona, California, Connecticut, Florida, New York, and South Carolina) that have laws requiring enrichment of all milled rice. However, enriched rice is readily available in all states. The U.S. Food and Drug Administration specifies (CFR 137.350) minimum levels of the micronutrients in all enriched rice, as shown in the table below. The fortification of folic acid is mandatory for all enriched grain-based products as stipulated by a U.S. government law passed in January 1998.

Minimum Micronutrient Contents in Enriched Rice in the U.S.

Micronutrient	Minimum amounts	
	mg/lb	mg/kg
B-1	2	4.4
Niacin	16	35
Folic Acid	0.7	1.5
Iron	13	28

Technological Capabilities - Current State

Micronutrient premixes are manufactured primarily by three companies: Research Products (Salina, KS); the Wright Enrichment Inc (Crowley, Louisiana); and Fortitech (Shenectady, NY).

Several types of enrichment methods exist as described below.

1. *Powder enrichment*: Powder premixes, dusted on to retail rice by millers using volumetric screw feeders, stick to the grain surface because of electrostatic forces. Usually a 1:1600 mixing ratio is recommended for powdered premixes. Powdered premixes are easier to manufacture and less costly than other premixes. To ensure that enrichment and other water soluble vitamins and minerals are not lost, consumers of rice fortified with powdered premixes are advised not to rinse the rice before cooking and not to cook it in excessive amounts of water and drain after cooking.
2. *Coated grain enrichment*: In this method, the micronutrient blend is coated to the surface of rice kernels using adhesives or other technologies like microperforation. Usually a 1:199 mixing ratio is recommended for grain premixes. Such premixes are more resistant to washing.
3. *Reformed grain enrichment*: Rice flour mixed with the micronutrient blend is extruded and reformed into kernels. These grain premixes are also added to rice in 1:199 ratio, and are more resistant to washing.

The U.S. enrichment manufacturers usually use powder and coated grain technologies for their premixes. Addition of premix to retail rice by the miller is a fairly simple process.

Research Products Company (RPC) (Salina, Kansas)⁵¹

⁵¹ Team member Sajid Alavi visited Research Products Company (Salina, KS) on November 13th, 2007 and met with CEO Monte Blanding and Vice President Patrick Clark.

RPC, a privately owned company with about 40 employees, has been supplying the milling and baking industry with maturing and bleaching agents, enrichment pre-mixes, and micro-ingredient dispensing systems since 1970. RPC currently manufactures over 80 different types of REPCO® brand enrichment concentrate premixes. Typically, these premixes are added to products such as milled rice, wheat flour, corn meal, grits, baked goods, breakfast cereals, and other processed foods. The micronutrients are sourced both from within and outside the U.S. RPC primarily caters to the domestic market, although its exports are increasing, primarily to Puerto Rico and the Philippines. RPC produces both powder micronutrient premixes (such as REPCO MR-16F), as well as a coated rice-premix (REPCO Type CR-2F). RPC's total sales of rice enrichments are evenly divided between the powder and grain premixes.

The REPCO Type MR-16F powder micronutrient premix is used for enrichment of milled rice, and contains the following micronutrients in a starch base:

Micronutrient content in powder micronutrient-premix REPCO MR-16F

Micronutrient	Source (Fortificant)	Amount (g/kg)
B-1	Thiamine mononitrate	7.0
Niacin	Nicotinic acid	56.4
Folic Acid	Folic acid	2.6
Iron	Ferric orthophosphate	74.1

The MR-16F powder premix, sold in 20 and 50 lb boxes, is added to milled rice by millers in a ratio of 1:1600 (i.e., 0.625 kg per metric ton of rice).

The REPCO Type CR-2F rice premix is a coated grain premix, which is prepared in batches using a horizontal rotary drum mixer (Rollo-Mixer Mark VI, Continental Products Corp., Milwaukee, WI)⁵². This mixer has a capacity of 4,000 pounds (~1,800 kg) and consists of a stainless steel rotating drum (88 inches in diameter) supported by two pillow block bearings. The bearings are supported by a steel frame that sits on a steel support base. The mixer drum has up to 12 spray nozzles for delivering an adhesive coating (ethyl cellulose) and pharmaceutical glaze to the milled rice, and rotates at about 3 rpm to achieve a uniform coating in 2-3 minutes. The mixer is equipped with a packager that automatically fills the coated grain premix into 50 lb bags. The recommended dilution rate over milled rice is 1:199 (i.e. 5 kilograms of rice premix per metric ton of rice).

The rice-premix contains the following micronutrients:

⁵² Powder and Bulk Engineering, December 1997, p 48-52.

Micronutrient content in rice-premix REPCO CR-2F

Micronutrient	Source (Fortificant)	Amount (g/kg)
B-1	Thiamine mononitrate	0.8
Niacin	Nicotinic acid	6.4
Folic Acid	Folic acid	0.28
Iron	Ferric orthophosphate	5.2

The average storage time of the premixes at RPC is 3 months, though the company claims a shelf life of 2 years. RPC enrichment premixes meet the CFR 137.350 standard of identity for enriched rice when added at the recommended proportions. With the powder micronutrient premix, there is the possibility of some separation and settling of the powder micronutrient premix from milled rice, but with the coated rice-premix, the enrichment firmly adheres to the surface of the grain. Each batch of raw ingredients and finished premixes is tested for the micronutrients to ensure strict quality control. RPC also extends its testing service to fortified rice from customers and claims that there is no change in product odor or color if the coating process is done correctly. The company is inspected annually by the Kansas Department for Health and Environment and also audited by AIB International for compliance with good manufacturing practices and hazard analysis critical control points. RPC is currently working towards ISO 22000 standards for food safety management.

RCP produces about 292 MT/year of micronutrient powder premixes and manufactures volumetric feeders (REPCO Model 70) for delivery of powder premixes to milled rice as well as other products.

Wright Enrichment Inc. (Crowley, Louisiana)

The Wright Enrichment Inc. in Crowley, Louisiana, produces 90 percent of the custom premixes in the U.S. They provide the package of premix to bring milled white rice up to the nutrient content of milled brown rice, plus they add folic acid. In addition the Wright provides equipment worth about \$2,000 that adds the micronutrient premix at a rate of 1 pound per 1600 pounds of rice.

Wright is producing about 2,624 metric tons of powder premix. Most of the ingredients for the premix are purchased in China. Iron, niacin, vitamin B-1, and folic acid are imported and shipped to premix producers. The filler in the premix is corn starch that can be purchased in the U.S. The cost of the micronutrients purchased in China is much less than in the U.S. The premix sells for about \$3.30/kg (\$1.50 per lb), and 1 lb will add the nutrients required for 1600 lbs of rice. Therefore, the cost per pound is less than one cent and does not directly impact the price of rice. The \$2,000 price for the equipment for adding the premix in the milling process may be provided by the pre-mix suppliers. Wright produces both grain and powder premixes for rice enrichment.

A typical powder premix (WL-161 with folic acid) has the following micronutrients levels:

Micronutrient content in Powder Premix (WL-161 with folic acid)

Micronutrient	Source (Fortificant)	Amount (g/kg)
B-1	Thiamine mononitrate	7.0
Niacin	Nicotinic acid	56.4
Folic Acid	Folic acid	2.5
Iron	Ferric orthophosphate	74.0

This powder premix is added to rice by millers in a ratio of 1:1600 to obtain 46.2, 35.2, 4.4 and 1.6 mg/ kg, respectively, of iron, niacin, thiamine (B-1), and folic acid in the fortified rice. The grain premix is produced at Wright using a different technology than the coating process employed by RPC. This proprietary technology involves embedding the enrichment in microperforations on the rice surface. This grain premix is added to rice by millers in a ratio of 1:199 to achieve the same levels of micronutrients as mentioned above.

Rice-premix is about 15 percent of the Wright Enrichment Inc. business. Other types of Wright enrichment technology include super coat where the nutrients are microencapsulated, supertab with direct compressible granulations, nutra rice for food aid, and coatings for iron rice and vitamin A rice. Wright has exported rice to the Philippines and Costa Rica. Recently, Wright exported iron-fortified rice to Viet Nam that was re-exported to the Philippines.

Farmers’ Rice Cooperative (FRC) (Sacramento, CA)

Farmers’ Rice Cooperative⁵³ is a typical example of a large U.S. rice miller. About 800 California farmers are affiliated with FRC, which is the only remaining rice cooperative in California. The other cooperative, Rice Growers Association, closed down 8 years ago, and all its farmers have slowly migrated to FRC. About 9-10 million cwt (or 400-450 thousand metric tons) of rough grain or paddy is processed annually by FRC, and its net production capacity of milled rice is 600 metric tons per day (or roughly 200 thousand tons per annum). FRC processes mostly Japonica variety medium-grain rice. Sales are evenly split between domestic and international markets, with regions like the Middle-East (Jordan), South Pacific, and Europe (mostly Scandinavian countries, Turkey, and Germany) dominating the latter. Selling price of FRC rice is \$0.57/kg (\$0.26 per lb).

Only about 5 percent of all rice produced by FRC is enriched and most of that is for export to regions like Guam. Although California law requires fortification of all rice, this requirement is not strictly enforced according to FRC representatives. Part of the reason for this is the vitamin-like medicinal odor in fortified rice that is not liked by consumers.

⁶Farmers Rice Cooperative (Sacramento, CA) or FRC was visited by team members Gail Cramer and Sajid Alavi on December 11th, 2007. The team met with Keith Hargrove (Vice President, Manufacturing & Technology) and Ken Cox.

FRC sources enrichment premixes from the Wright Enrichment Inc. and Research Products Co. in 50 lb boxes, the cost of which averages \$3.30/kg (\$1.50 per lb). Fortification costs are typically not passed on to the buyer. The process used for fortification is the dusting method using volumetric screw feeders, usually dry feeders with 2-3" diameter screws manufactured by Pennwalt, Wright, or RPC. Such feeders typically cost roughly \$2,000-\$5,000. The feeder delivers the powder premix to the milled rice in a ratio of 1:1600. FRC does not have any in-house lab facilities to test levels of vitamins and minerals in the fortified rice. Quality control of the fortification level is ensured by periodic calibration of the feeders. Samples are sent to outside laboratories such as Silliker Labs if chemical tests are required.

Costs Associated with Fortification

The costs associated with the coating and dusting methods are discussed below.

Coating method

The capital cost for the roller drum needed for the coating process is about \$300,000. The drum should last approximately 20 years. Therefore, the annual capital and interest cost are about US\$27,000 (Table 1), which is less than 3 percent of the final cost. Purchasing rice (about US\$576,000) that will be covered with the micronutrient layer is the main cost of the operation (about 59 percent of the total), while the fortificant mix represents 18 percent of the total cost (about US\$180,000). For this micronutrient formula, the fortificant mix has little influence on the total cost. The estimated cost of this rice-premix is US\$0.98/MT.

With a dilution factor of 1:200 for the coated rice-premix, the cost of rice fortification is US\$4.90/MT. The costs for the feeder and quality assurance, which represent no more than 10-20 percent of the total cost of the operation, should be included in the overall cost. When these costs are included, the overall cost to fortify rice using coated rice-premixes is between US\$5.50 and US\$6.00/MT. At a consumer price in the United States of US\$0.50-1.00/kg, the additional cost of fortification, using coated rice-premix, represents a price increment of between 0.6-1.2 percent.

Dusting method

The powder micronutrient premixes sell for about US\$3.30/kg (i.e. \$1.50/lb). With a dilution factor of 1:1,600 for the powder micronutrient premixes, the cost of rice fortification is US\$2.06/MT⁵⁴. The U.S. uses about 2,650 metric tons of the premix per year, which is easily supplied by the existent factories that have the capacity to produce 30 MT/day (i.e. 10,000 MT/year). The cost to manufacture all this powder premix and to distribute the premix to millers is about \$8.7 million per year.

As with the coated pre-mix, costs for the feeder and quality assurance, which represent between 10-20 percent of the total cost of the operation, should be included in the overall cost of the dusting method. When these costs are included, the overall cost to fortify rice using powder micronutrient-premixes in the U.S. is about US\$10.2 million, or about US\$2.40/MT. At a consumer price in the United States of US\$0.50-1.00/kg, the additional cost of fortification, using micronutrient-premixes, represents a price increment of 0.2-0.5 percent.

⁵⁴ The cost points in this report are points on a short run cost curve and do not represent the long run cost curve.

The cost of the fortification program is determined and borne by the free market. Part of the cost is passed on to consumers in terms of a slightly higher price, and the remainder is absorbed by the producers in terms of a slightly lower profit.

Table 1. Economic analysis of rice-premix manufactured by coating method (based on production of 1,000 metric tons per year) in the United States

<u>Capital Cost</u>			
	Drums and sprayer	\$	300,000
 <u>Annual Costs</u>			
		\$	
	Capital ⁵⁵		15,000
	Interest ⁵⁶		12,000
			27,000
	Administration		60,000
	Labor		50,000
	Electricity		12,000
	Water		3,000
	Repairs		6,000
	Wax		30,000
	Fortificant (20 MT x 9.00/kg) mix		180,000
	Rice Grain(960 MT x0.60/kg)		576,000
	Packaging		6,000
	Wooden pallets		30,000
			980,000
	Total annual costs	\$	980,000

Note: The cost figures in this table are for a generic coating operation, not for any specific firm.

Total cost per kg: \$ 0.98.

Total cost per metric ton of enriched rice \$4.90

⁵⁵ Assumes 20 years of useful life.

⁵⁶ Assumes that the average cost of financing over the 20-year period is 4 % of the total capital value.

