The Research Behind the Ultra Rice® Technology

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The Research Behind the Ultra Rice® Technology

Summary

Ultra Rice grains are a micronutrient-fortified manufactured food product designed with the flexibility to address specific nutritional deficiencies in populations where rice is a staple food. This review summarizes the research to date on the Ultra Rice technology, most of which was conducted during product development and therefore remains proprietary. Details on key studies are provided in Appendix A, organized into seven categories (safety, stability, bioavailability, efficacy, effectiveness, sensory evaluation, and cost), listed in chronological order. All information made available to PATH is included in the review; however, PATH has limited access to information on local market research conducted by companies to evaluate their own investment decisions for Ultra Rice production.

Shelf life and stability of nutrients have been the major focus of the research. Lessons learned have led to development of a new formula that can meet label claims for six months. Safety is mainly a concern regarding vitamin A; however, studies show there is a large margin of safety at levels likely to be used. Bioavailability for both vitamin A and iron is high for the compounds now used. The vitamin A in Ultra Rice has been shown to improve vitamin A levels in children and pregnant women, and in one case, this was shown in a real-life program setting. A study of the efficacy of a form of Ultra Rice fortified with SunActive® iron pyrophosphate is ongoing.

Sensory evaluations suggest that few consumers can detect smell or taste differences between fortified and unfortified rice. More serious are visible differences in the Ultra Rice grains, since many consumers assume the rice is of lower quality and try to pick the kernels out. The biggest challenge in this respect is adding iron. Pyrophosphate forms do not change the color and are therefore the best choice.

In sum, Ultra Rice has now undergone adequate testing to be ready for widespread use in fortification programs.

Introduction and Background

Ultra Rice grains, made from extruded rice flour, resemble natural milled rice grains in size, shape, color, and density and convey no taste or smell to uncooked or cooked rice. PATH has developed two separate varieties of Ultra Rice grains—one carrying vitamin A, the other carrying iron, zinc, thiamin, and folic acid. All the ingredients are approved for use in food products and are added at levels acceptable by international regulatory standards such as the *Codex Alimentarius*. No animal products (such as animal fats) are included.

Ultra Rice is a registered trademark in the United States of Bon Dente International, Inc.
SunActive is a registered trademark of Taiyo International.

Ultra Rice dough is extruded into kernels.

The unique advantage of the Ultra Rice technology is its ability to protect micronutrients within the manufactured grain, thus limiting nutrient degradation losses in storage, as well as during the rinsing and cooking steps of food preparation. Ultra Rice grains are blended with local rice in ratios that can vary according to the fortification levels required, but usually approximate 1:100. The process for manufacturing Ultra Rice grains typically utilizes existing pasta-extruding facilities during hours when equipment is idle, thereby keeping costs low and reducing the need for substantial on-site capital investment.

Research issues related to food fortification

Food fortification is a long-term sustainable approach to preventing micronutrient malnutrition. During product development of fortified foods, a number of studies are typically conducted to explore technical issues related to safety, efficacy, cost, nutrient stability during manufacturing, and the shelf life of the fortified food in terms of both nutritional and organoleptic qualities. Animal studies may be pursued, particularly for those nutrients whose bioavailability is uncertain. Stability studies are usually done to see how well the fortified food holds up under various conditions. Human feeding trials may be done to ensure that the final formulation is safe and effective in normalizing nutrient status. Research may also include assessing the safety of consuming higher than normal levels of fortificants. Pre-market and post-market consumer studies are done to see if the fortified food is acceptable with respect to smell, texture, taste, and appearance. Other studies might research market feasibility, consumers' willingness to purchase the fortified food at different prices, and their knowledge about health issues such as the importance of vitamins and minerals in the diet.

Historical periods in the development of Ultra Rice technology

The Ultra Rice technology was developed in the 1980s by Bon Dente International, Inc., a research and development company based in Lynden, Washington, USA. With support from governmental organizations, academia, and industry, Bon Dente was successful in creating Ultra Rice grains that contain vitamin A. Early formulas underwent independent testing by the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS), Iowa State University, and the University of Pernambuco in Brazil. PATH was not involved in this early product development stage and therefore does not have access to some of the early product development research.

In 1994, PATH began working with Bon Dente in some of the investigations required before this technology could be commercialized and scaled up for use in developing-country settings. The intellectual property associated with the Ultra Rice technology was donated to PATH in 1997, in recognition of PATH's expertise in public-/private-sector collaborations and to ensure its introduction in developing countries on the broadest scale possible. Neither PATH nor Bon Dente received monetary or other compensation for this exchange. All research done on Ultra

Rice since that time has been commissioned by PATH or done by independent researchers with Ultra Rice grains provided by PATH. PATH obtained a five-year grant from the Bill & Melinda Gates Foundation in 1999 to demonstrate the manufacturing feasibility of adding iron, zinc, thiamin, and folic acid using the Ultra Rice technology; to demonstrate the bioavailability of these micronutrients and their effectiveness in alleviating deficiencies in affected populations; and to commercialize appropriately fortified versions of Ultra Rice in developing countries.

Ultra Rice was originally conceived of as a vehicle for providing vitamin A, and most early research focused on the safety, formulation, appearance, and shelf-life challenges related to that nutrient. By 2003, PATH finalized an updated vitamin A formula that offers better micronutrient stability at lower cost. This stable formulation was modified further to produce a separate variety of Ultra Rice grains containing iron, zinc, folic acid, and thiamin.

The use of the nutrients zinc, folic acid, and thiamin is straightforward in food fortification programs; these nutrients are generally not associated with adverse effects and thus were subject primarily to stability research. Due to the challenge of adding iron as a fortificant, PATH undertook a systematic assessment regarding a range of issues, including machinability, appearance, taste, shelf life, cost, and bioavailability. Though this assessment is largely complete, a study of the bioavailability of one form of iron in Ultra Rice is ongoing among non-pregnant women in Mexico.

Safety

Some nutrients can be dangerous if consumed in extremely high levels. Research on the safety of Ultra Rice has focused on vitamin A. In the early stages of product development, one male volunteer in Brazil consumed 25 g of undiluted Ultra Rice grains daily for 20 days (containing 66,000 IU of vitamin A per day) with no detectable adverse effects (Flores et al. 1994). Since then, hundreds of thousands of people have consumed rice fortified with Ultra Rice, and no adverse effects have been reported.

Consumption of large amounts of vitamin A in the form of a supplement (capsule) leads to increased levels of circulating retinoic acid, which can cause teratogenicity (birth defects) in the fetus. However, vitamin A in food results in much lower increases in retinoic acid (1/20 as much in one study comparing liver to capsules) (Buss et al. 1994). One study observed the effects of consuming rice fortified to contain 12 times the recommended daily allowance per serving for vitamin A (Berti et al. 2001). The impact of consuming 30,000 IU in a 100-g serving of fortified rice was measured on plasma retinol values of non-pregnant volunteers in Toronto, Canada. The impact of consuming 20,000 IU in a 100-g serving of fortified rice was also tested on non-pregnant volunteers in Recife, Brazil. The increases in serum retinol concentrations were modest, with the highest individual spike value 228% of the baseline value. This would probably lead to negligible increases in retinoic acid and thus was deemed safe.

The World Health Organization (WHO) estimates that long-term daily consumption of 10,000 IU of retinol in capsule form is safe even in pregnancy. In current Ultra Rice programs, the fortification levels chosen are much below those tested above. In Colombia, for example, a woman would need to consume 1,000 g of uncooked rice, which would translate to about 2,400 g of cooked rice, to achieve an intake of 10,000 IU from fortified rice alone. To achieve the same high intake in Brazil, 1,600 g of uncooked rice or about 4,000 g of cooked rice would need to be consumed. It is virtually impossible that this could happen, particularly on a regular basis. WHO estimates that a single pharmaceutical dose of 25,000 IU is safe. Thus, in any plausible scenario in which a higher level than 10,000 IU was consumed for a short period, there is still a large margin of safety. Those in greatest danger of consuming more than 10,000 IU per day in their normal diets would be people regularly consuming liver (which is rare) or taking high-dose vitamin supplements. There are no other likely scenarios in which retinol would be high in baseline diets, and carotene, which the body can transform to retinol, does not lead to teratogenic risks, even in high doses.

Theoretically, in the first trimester of pregnancy, over-consumption of vitamin A-fortified Ultra Rice grains that has not been blended with normal rice could lead to risks of teratogenesis. This is unlikely to happen, however, since Ultra Rice is delivered to consumers pre-blended with polished white rice. The longest experience to date in a developing-country setting with a vitamin A-fortified food product is sugar in Guatemala and other Central American countries. The level of vitamin A provided would deliver the maximum daily amount for pregnant women of 10,000 IU with the consumption of only 200 g of sugar a day (much more likely than the consumption of 1,000 g of rice), yet there have been no reports of toxicity. Similarly, despite the wide range of fortified foods available in the United States, no alarms have been sounded in this regard.

It is generally accepted that the other nutrients in Ultra Rice do not lead to any risk of adverse effects at the levels present in fortified rice. This is also true for high nutrient concentrations that are likely to be ingested when large amounts of fortified rice are consumed, even among people who are nutritionally replete. Thus, research related to potential toxicity has not been prioritized.

Shelf Life/Stability

Many early studies (Murphy et al. 1989 and 1992, Flores et al. 1994, Murphy et al. 1996, Hamer 1998, Cantu and Dranow 1998, Cori 1999, Lee et al. 2000, Philippines NFA 2002, Bett-Garber et al. 2004, Diosady 2003, Rief 2004) examined various indicators of shelf life in the early formulations of Ultra Rice: fat rancidity and the proportion of baseline nutrients present after food processing (particularly washing), cooking, and storage under various conditions of heat and humidity. Lessons learned have led to a new formulation with different binders and antioxidants and different forms of vitamin A and iron.

A study was conducted in Colombia (Rief 2004) to determine the stability over time of the original locally manufactured vitamin A variety of Ultra Rice. This was done to determine whether the micronutrient overages (excess added to account for losses) used for production were adequate. Based on this study, the Ultra Rice team made formulation recommendations to improve the stability of the product.

Other recent studies (Diosady 2003; Diosady and Li 2004, 2005) have examined how well the current formulation of Ultra Rice grains holds up when stored for up to six months under extreme conditions—up to 45° or 60°C and 100% relative humidity. Iron, zinc, and folic acid were completely retained, and thiamin and vitamin A were over 80% retained. Ultra Rice is now fortified with iron pyrophosphate, which is stable during storage, creamy white in color, and does not cause oxidation (rancidity) of the fat in the Ultra Rice grains, so that little effect on taste is likely after six months of storage.

Bioavailability

Used in relative dose response tests among 83 children aged one to six in Brazil (Flores et al. 1994), vitamin A-fortified Ultra Rice performed identically to the same amount of vitamin A (1,500 IU) provided in standardized forms for such tests. This suggests that the vitamin A in Ultra Rice is adequately absorbed and transported.

Rat studies were conducted to compare the relative bioavailability of various forms of iron pyrophosphate fortificant to ferrous sulfate (Hunt 2004). SunActive iron pyrophosphate proved to be nearly as bioavailable as ferrous sulfate and significantly more bioavailable than any of the other forms of ferric pyrophosphate tested. The other three forms of iron pyrophosphate analyzed showed similar bioavailability at about 75% relative to ferrous sulfate.

Efficacy

In Brazil (Flores et al. 1994b), the biological efficacy of vitamin A-fortified Ultra Rice was tested. Eighty-three children (aged 11 to 77 months) were fed the fortified rice (1,500 IU per 100-g serving) for 30 days. Mean serum retinol level increased from 1.09±0.40 to 1.65±0.51 umol/L. At baseline, 51% of the children presented with levels below the cut-off for mild deficiency (1.05 umol/L) compared to 8.8% at endpoint.

In Nepal (Haskell et al. 2005), Ultra Rice was included as one of six treatment groups in a vitamin A trial of 69 women in their final two months of pregnancy. They received 850 μg retinol equivalents per day for six days a week for six weeks. All of those who were night blind in the Ultra Rice group reported that the night blindness disappeared (this normally does not happen until after delivery). The mean adjusted pupillary threshold (a measure of dark adaptation, in turn influenced by vitamin A status) in the Ultra Rice group improved from a mean of -0.7 at baseline to -1.3 after seven weeks (proposed cut-off for normal is -1.1). The Ultra Rice formulation used in this trial contained α-tocopherol as an antioxidant (currently excluded, but only for cost reasons), and the Ultra Rice group improved more in serum α-tocopherol levels than all the other groups (this was statistically significantly greater than two of the other groups).

Effectiveness

In Brazil, six day care centers for preschool children were provided with Ultra Rice fortified at a level of about 1,500 IU per serving for a trial lasting one year (Flores et al. 1994b). Serum retinol values continually increased at each of the four-monthly measurements up to one year of age. After a full year, no children were deficient according to the relative dose response test, compared to 44% at baseline. There were no major differences in children in these experimental preschools compared to children in nearby preschools in diet or growth during the study year. There were only slight differences in morbidity (mainly in favor of the Ultra Rice group).

Sensory Evaluation

Sensory evaluations of earlier formulations have given varying results, but generally only a small proportion of consumers appear to reject the fortified rice based on the minor differences they can perceive (Flores et al. 1994, Hermana 1995, Cori 1999, Bett-Garber 2004, IMRB 2003). The most problematic was Ultra Rice fortified with ferrous sulfate, which gave the grains a brownish-gray color that contributed to its often being dry-picked (IMRB 2003). Yet when served with a sauce, very few consumers could detect its presence in a 1:100 blend. Clearly, ferric pyrophosphate as a fortificant is the most acceptable form of iron to consumers, outperforming sodium iron EDTA (Consultor Apoyo, 2003).

Cost

Once its benefits were explained, consumers in both India and Ecuador (IMRB 2003, Consultor Apoyo 2003) stated their willingness to purchase fortified rice. In a test trial in one district in Indonesia (PATH 1997) following a social market campaign, consumers actually paid 10 to 20 percent more than for unfortified rice in their local markets. In Colombia and Brazil, the addition of Ultra Rice, fortified at about one-third of the recommended dietary allowance with vitamin A, thiamin, iron, zinc, and folic acid for a 100-g portion, increases the cost to the producer by only a few percent.

About PATH

PATH is an international, nonprofit organization that creates sustainable, culturally relevant solutions, enabling communities worldwide to break longstanding cycles of poor health. By collaborating with diverse public- and private-sector partners, we help provide appropriate health technologies and vital strategies that change the way people think and act. PATH improves global health and well-being.

PATH currently works in more than 100 countries in the areas of reproductive health; vaccines and immunization; HIV, AIDS, and tuberculosis; and children's health and nutrition. Headquartered in Seattle, Washington, since its inception in 1977, PATH operates 18 offices in 13 countries.

For more information, please visit www.path.org.

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Diosady L, Li OY. *Phase 1 Report on the Development and Stability Testing of an Iron-Containing Formulation of Ultra Rice* [unpublished report]. Toronto, Canada: Food BioTek Corporation; 2004.

Flores H, Campos FACS, Silva MBM, Lins MH, Barretto E, Albuquerque S. *Efficacy of Vitamin A Enriched Rice in the Treatment and Prevention of Vitamin A Deficiency* [unpublished report]. Recife, Brazil: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco; 1994.

Flores H, Guerra NB, Cavalcanti ACA, Campos FACS, Azevedo MCNA, Silva MBM. Bioavailability of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1994;59(2):371–372, 377.

Hamer M. *Multiple Fortification of Rice* [report prepared for Productos Roche Ltda. and Task Force Sight and Life]. Seattle: PATH; 1998.

Haskell MJ, Pandey P, Graham JM, Peerson JM, Shrestha RK, Brown KH. Recovery from impaired dark adaptation in nightblind pregnant Nepali women who receive small daily doses of vitamin A as amaranth leaves, carrots, goat liver, vitamin A-fortified rice, or retinyl palmitate *American Journal of Clinical Nutrition.* 2005;81:461–71.

Hermana H. *Acceptability Test of Ultra Rice* [unpublished report]. Bogor, Indonesia: Nutrition Research and Development Centre, National Institute for Health Research and Development, Ministry of Health; 1995.

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Philippines National Food Authority (NFA), Food Development Center. *Iron Retention of Ultra Rice Premix in the Iron Fortified Cooked Rice* [unpublished report]. Manila, Philippines: NFA; 2002.

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Appendix A

Summaries of Ultra Rice® Studies

The following summaries cover the research done to date on the Ultra Rice technology, most of which was conducted during product development and therefore remains proprietary. The studies are organized in seven categories, listed in chronological order. Some studies are relevant to more than one category. All information made available to PATH is included in the review; however, PATH has limited information on local market research conducted by companies to evaluate their own investment decisions for Ultra Rice production.

Safety

Berti PR, Fitzgerald S. *Advancement of Vitamin A Fortified Ultra Rice* [unpublished report]. Ottawa, Canada: PATH Canada; 1999.

The authors calculate that the maximum level of vitamin A required to meet normative vitamin A requirements for children one to six years old consuming 20% of their energy as rice would be 17 IU/g of cooked rice. The level potentially of concern in pregnancy would be 30 IU/g. *[Current Ultra Rice programs in Colombia and Brazil fortify at 10 IU/g or less.]*

Berti PR, Krasevec J, Flores H, Schauer C. *Total Serum Retinol Levels After Consumption of Vitamin A Fortified Ultra Rice* [report prepared for PATH]. Ottawa, Canada: PATH Canada; 2001.

Author affiliation: PATH Canada (Berti); Federal University of Pernambuco, Brazil (Flores); and University of Toronto, Canada (Schauer).

Objective: To test if circulating retinol remains within homeostatic control after the intake of rice fortified with 6 and 12 times the RDA (per single meal) in non-pregnant women.

Method: Twenty-six women were recruited in Toronto, Canada, to receive either 15,000 or 30,000 IU vitamin A and 25 women in Recife, Brazil, to receive either 10,000 IU or 20,000 IU, in each case in 100 g uncooked rice (including a 25% overage to account for cooking losses). Serum retinol was measured at baseline and 3, 5, 7, and 24 hours after ingestion.

Results and discussion: The changes in levels of serum retinol measured were on average 25%–50% above baseline levels, and no individual increased more than 2.5 times baseline levels. This can be compared to one study of the impact of giving 50,000 IU, which resulted in nearly a mean quadrupling of baseline levels, with a maximum above six times the mean baseline level.

The authors argue that risks for acute or chronic vitamin A toxicity from eating Ultra Rice are basically zero since the levels that would need to be consumed are beyond plausibility. Thus the only risk requiring attention is the risk of consuming undiluted Ultra Rice grains during the first trimester of pregnancy, when teratogenicity is a concern.

Retinoic acid is actually the substance thought to produce teratogenicity. Its production is believed to result from a very rapid absorption of retinol, resulting in temporary saturation of retinol-binding protein sites and shunting of metabolism toward the production of retinoic acid. Retinol in food is absorbed much more slowly and was found in one study of liver consumption to lead to only 1/20 the levels of retinoic acid production per quantity of retinol ingested compared to vitamin A capsules.

The literature is ambiguous and incomplete, but certainly supplementation (capsules) with 6,000 IU per day is safe ("no observed adverse effect" level), and the World Health Organization's recommendation is to limit this type of consumption to 10,000 IU. Thus, levels of vitamin A ingestion plausible, even with unusually high levels of consumption of fortified rice (600 g of uncooked rice = 30,000 IU at the level used in this study), are likely to lead to levels of retinoic acid several times below the levels suspected to be unsafe.

Flores H, Guerra NB, Cavalcanti ACA, Campos FACS, Azevedo MCNA, Silva MBM. Bioavailability of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1994;59(2):371–372, 377.

Author affiliation: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco, Recife, Brazil.

Method: One adult volunteer was fed daily, for 20 days, 25 g (containing 66,000 IU of vitamin A—more than 25 times the daily dose intended for the children) of cooked Ultra Rice.

Premix ingredients:

- Vitamin A (@ 800 µg retinol/g premix): all-trans retinyl palmitate (type VI; 1,800,000 IU/g, without vegetable oil (Sigma Chemical Co.)
- Shortening: corn oil, lard
- Antioxidants (@ 1 mg/g premix): alpha-tocopherol (Spectrum Chemical), BHA (VWR), ascorbic acid (Sigma Chemical Co.)
- Rice flour

Blend ratio: 2% (2 g premix/100 g fortified rice)

Vitamin A concentration per 100-g serving (daily intake): 1,330 IU vitamin A (400 µ retinol)

Cooking method: 5 min. boiling followed by 20–25 min. under low heat

Pre-stability exam: Storage up to 180 days, protected from direct light in a cool place (~26ºC), Aw ~0.7, moisture ~12%. Average vitamin A concentration (µg retinol/g premix): 872.8±7.5 (9), 662.7±31.6 (16), 618.5±11.8 (24), 630.8±6.3 (24) at days zero, 37, 71, and 180, respectively.

Results: After this period of observation, standard clinical, physical, and laboratory evaluations were carried out. No adverse effects were detectable by clinical examination or standard laboratory evaluation.

Stability

Note: The studies summarized below are based on earlier formulations for Ultra Rice which are no longer in use. They are included to indicate the progression of research and lessons learned in coming up with the current improved formulation.

Murphy PA, Fratzke A, Hauck C, O'Connor K. *Fortification of Ultra Rice with Vitamin A* [unpublished report]. Ames, Iowa: Department of Food Technology, Iowa State University; 1989.

Study supported by the U.S. Department of Agriculture, Office of International Cooperation and Development, and the U.S. Agency for International Development, Bureau for Science and Technology, Office of Nutrition.

Methods: Initial attempts to fortify Ultra Rice with vitamin A (Ultra Rice I) used retinyl palmitate oil. Since it contained only minimal quantities of BHA and BHT as antioxidants, the resulting product yielded unacceptably high losses of vitamin A. Ultra Rice II and III were prepared using retinyl palmitate 250 SD (stabilized in an acacia matrix). Rinsing test results showed that these forms of Ultra Rice retained most of the vitamin A content. Cooking tests were done using undiluted Ultra Rice, without excess water. Ultra Rice II was more stable than Ultra Rice I, but less stable than earlier fortified wheat products. Ultra Rice III had greater stability, though half the vitamin A was lost after 7 to 9 weeks.

Results: Ultra Rice II and III demonstrated that the product could be made in replicate and that a rinse-stable product could be produced. Increasing the content of antioxidants, reducing heat and oxygen during production, and reducing oxygen exposure of the Ultra Rice would lengthen shelf life.

Murphy PA, Smith B, Hauck C, O'Connor K. Stabilization of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1992;57(2):437–439.

Author affiliation: Department of Food Science & Human Nutrition, Iowa State University, Ames, Iowa (Murphy, Smith, and Hauck); Minnesota Valley Testing Laboratories, New Ulm, Minnesota (O'Connor).

Methods: A synthetic rice premix used for vitamin A fortification was tested for stability after washing and cooking, and for long-term chemical stability of the vitamin A. In an attempt to evaluate the thermodynamics of vitamin A loss, accelerated storage studies were conducted at three to four temperatures and two water activities (Aw). The effect of different formulation ingredients on stability kinetics was evaluated.

Ultra Rice fortified with retinyl palmitate 250 SD was prepared for initial evaluation using a pasta extruder to make batches of premix with d-l-alpha-tocopherol or BHA/BHT combinations. Tocopherol was tested with and without added ascorbate as a synergist.

Results: Washing tests compared the vitamin A content of dry premix to the premix that had been stirred in water for 5 minutes. All of the vitamin A (100%) was retained. Cooking tests measured the retention of vitamin A after 5 minutes cooking time in boiling water. All cooking water was absorbed by the Ultra Rice. Half-life ($t_{1/2}$) was calculated as time required for 50% of vitamin A to degrade. The Ultra Rice had cooking retentions of vitamin A from 46% to 94%. Cooking stability of vitamin A in Ultra Rice diluted with ordinary rice yielded results similar to stability of the premix alone. Based on preliminary Ultra Rice accelerated stability studies, it was determined that lipid and antioxidant types have a role in the overall vitamin A stability.

Lipids with lower levels of unsaturation increased vitamin A stability. Long-term stability of vitamin A in these formulations at low humidity (Aw = 0.11) was very good. Combinations of more saturated oils, tocopherols, and ascorbate are recommended for adequate preservation of vitamin A in the synthetic rice premix.

Flores H, Guerra NB, Cavalcanti ACA, Campos FACS, Azevedo MCNA, Silva MBM. Bioavailability of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1994;59(2):371–372, 377.

Author affiliation: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco, Recife, Brazil.

Method: Ultra Rice premix was stored for 180 days at 26°C and 70% humidity.

Results: Initial loss was 25%, after which vitamin A values stabilized. The loss during normal cooking was about 26%. *[Note: this is an early formulation, no longer used.]*

Murphy PA. Technology of vitamin A fortification of foods in developing countries. *Food Technology*. 1996:69–74.

Author affiliation: Department of Food Science & Human Nutrition, Iowa State University, Ames, Iowa, USA.

Ultra Rice was subjected to accelerated storage studies to simulate tropical temperature and humidity. It was determined that the type of lipid and antioxidants used in the rice formulation were significant factors in the chemical stability of vitamin A. A combination of several antioxidants working synergistically was needed to maximize vitamin A stability for such environmental conditions. More saturated vegetable oils yielded a more stable rice product.

Attempts were made to co-fortify the synthetic rice with vitamin A and iron but were unsuccessful due to discoloration during storage of the co-fortified synthetic rice and oxidation of vitamin A by the iron.

Hamer M. Multiple Fortification of Rice [report prepared for Productos Roche Ltda. and Task Force Sight and Life]. Seattle: PATH; 1998.

Cantu T, Dranow P. *Fortification of Ultra Rice* [Food Applications Laboratory Technical Services Report to Roche Latin America]. Nutley, NJ: Hoffmann-La Roche; 1998.

Cori H. ***Report on Experience in Multiple Fortification of Rice through the Simile Grain Technology (Ultra Rice)*** **[internal report]. Santiago, Chile: F. Hoffmann-La Roche, Latin American Regional Center; 1999.**

Lee J, Hamer ML, Eitenmiller RR. Stability of retinyl palmitate during cooking and storage in rice fortified with Ultra Rice fortification technology. ***Journal of Food Science.*** **2000;65:915–919.**

Author affiliation: Department of Food Science and Technology, University of Georgia, Athens, Georgia, USA; PATH, Seattle, Washington, USA.

Rice fortified with Ultra Rice containing retinyl palmitate (RP) was tested as a potential vehicle for vitamin A delivery. After Ultra Rice was mixed with a long-grain rice at the ratio of 1 to 99 (w/w), the stability of RP in the rice mixture was studied during cooking and storage for 6 months. After cooking, the percent retention of RP ranged from 75 to 87 depending upon the cooking methods. The stability of RP in the rice stored at two different temperatures and relative humidities (RH) appeared to be more affected by temperature than RH. Therefore, under tropical conditions, rice fortified with RP should not be stored for long periods at high temperatures to avoid significant RP losses.

Methods:

Premix ingredients:

- Vitamin A (@ 2500 IU/g premix): all-trans retinyl palmitate (RP, Palmabeads, type 500; 500,000 IU/g; dispersed in a gelatin matrix with sucrose, peanut oil, tricalcium phosphate, BHA, and BHT) (Roche Vitamins and Fine Chemicals)
- Shortening
- Antioxidants
- Rice flour

Blend ratio: 1% (1 g premix/100 g fortified rice)

Cooking method: (1) 200 ml water to 100 g rice, 20 min. in a rice cooker; (2) 200 ml water to 100 g rice, cooked covered over low heat 20 min. after being brought to a boil; and (3) 400 ml water to 100 g rice, cooked covered over low heat 20 min. after being brought to a boil. Excess water collected and assayed for residual RP.

Stability testing relative humidity: 55% and 80%

Stability testing temperatures: 0, 23, and 35°C.

Results: Cooking significantly reduced the RP content in the samples cooked by the rice cooker and by boiling in excess water. Boiling without excess water did not significantly affect the RP content. For samples cooked in excess water, about 20% of RP was measured in the excess water.

The RP content of the samples stored at 0°C under nitrogen gas was not significantly different from the RP in the samples stored at 23°C. A significant difference in RP stability between the samples stored at 23°C and the samples at 35°C was observed, but no difference in the stability was found between 55% and 80% RH throughout 24 weeks of storage within the same temperatures. The stability of RP thus appeared to be more affected by temperature than RH. When stored at 23°C for 6 months, 85% of the RP was retained.

Philippines National Food Authority (NFA), Food Development Center. *Iron Retention of Ultra Rice Premix in the Iron Fortified Cooked Rice* [unpublished report]. Manila, Philippines: NFA; 2002.

Objectives: (1) Determine the retention of iron after washing and cooking of iron-fortified rice made from Ultra Rice premix, expressed as percentage retention, and (2) determine the effect of the Ultra Rice premix on the color and flavor of cooked fortified rice.

Results: Iron retention of cooked fortified rice (made with Ultra Rice premix) varied with the amount of premix added. At a ratio of 1:100, the retention was 62.5%. At a ratio of 1:150 the retention was 81.9%. Iron fortified cooked rice (made with Ultra Rice premix) had a perceptible to slight grayish discoloration. The perceptible grayish discoloration was identical to that achieved using current Food Development Center (FDC) iron rice premix at 1:150 blend ratio. Fortified rice made from FDC iron rice premix was acceptable to 2,100 families and 45,170 school children who purchased the product as part of the Department of Social Welfare and Development Rice Subsidy Program and Department of Education, Culture and Sports Breakfast Feeding Program, respectively.

Conclusion: Fortified rice made from Ultra Rice premix had better iron retention compared with fortified rice made from FDC iron rice premix. The color and flavor of fortified cooked rice made from Ultra Rice premix were identical to the fortified cooked rice made from FDC iron rice premix at 1:160.

Bett-Garber KL, Champagne ET, Ingram DA, Grimm CC. Impact of iron source and concentration on rice flavor using a simulated rice kernel micronutrient delivery system. *Cereal Chemistry*. 2004;81:384–388. *Based on research done in 2001.*

Author affiliation: Southern Regional Research Center, Agricultural Research Service, United States Department of Agriculture; New Orleans, Louisiana, USA.

Methods: An extruded grain designed to look like a rice kernel fortified with one of two sources of iron (elemental iron and FeSO4), zinc, thiamin, and folic acid was mixed with milled Calrose rice at ratios of 1:50, 1:100, and 1:200. Product stability was determined by gas chromatographic analysis of lipid oxidation products. Four formulations were analyzed to determine the development of lipid oxidation products during storage: (1) elemental iron, (2) elemental iron plus multiple fortificant (zinc, folic acid, and thiamin), (3) ferrous sulfate (FeSO4), and (4) FeSO4 plus multiple fortificants. The storage conditions were ambient (25ºC) and accelerated (40ºC). Samples were stored in cotton bags and zip-closure polyethylene bags. Sampling was done at 0, 1, 2, 3, 4, 5, and 6 months.

Samples consisted of 0.75 g rice in a 2-ml vial with a Teflon seal. Samples were spiked with a 2-ml aliquot of a 1 ppm solution of 2,4,6-trimethylpyridine (TMP) in water, which served as the internal standard. Samples were preheated for 5 min. at 60ºC prior to sampling. Collection of volatile compounds was accomplished using a 15 min. adsorption period at 60ºC while agitating the sample.

Oxidation was determined by changes in the concentration of nonanal (a lipid oxidation product) during storage. Although trimethylpyridine was added to all samples as an internal standard, a large variation in its recovery was observed, rendering any normalization techniques suspect. The recovery of the internal standard was noticeably less in samples containing FeSO4, which coincidentally contained large concentrations of lipid oxidation compounds in the headspace. The concentration of volatile compounds increased until month 2 or 3, then a noticeable drop was observed, with only slight variations observed in the concentrations for months 4, 5, and 6.

Results: The treatments with multiple fortificants produced less volatile lipid oxidation products than those without. In general, the addition of elemental Fe resulted in a lower concentration of lipid oxidation products in the headspace than FeSO4 by nearly a factor of 2 for storage times of two months and longer. This held for both samples with iron plus multiple fortificant and iron only.

Concentrations were similar for the first 1 to 2 months when comparing ambient vs. accelerated temperature. At extended storage periods, there are more volatile compounds found in rice held at ambient temperature than at accelerated temperature. This was true regardless of packages. The expectation was that storage at accelerated temperature would promote volatile compound formation. A possible explanation is that volatile compounds in the heated samples were readily released from the rice prior to gas chromatographic analysis.

Packaging appears to have made little difference, especially over an extended period of time. The accelerated treatments gave similar results for the plastic and cotton packaging at 4, 5, and 6 months. The same held true for the ambient stored rice over all four treatments. In conclusion, rice fortified with elemental iron alone or with multiple fortificants had better storage characteristics than that fortified with ferrous sulfate alone or with multiple fortificant.

Diosady L. *Antioxidant Systems for the Preservation of Vitamin A in Ultra Rice* [unpublished report]. Toronto, Canada: Food BioTek Corporation; 2003.

Objective: Review, test, and reformulate the antioxidant components of the Ultra Rice formula.

Methods: Twenty formulations were tested, including four commercial vitamin A powders, comparing their stability to the original Ultra Rice formulation. Ten antioxidants in various combinations were tested in extruded rice stored for up to six months at 25°, 35°, or 45°C and 60% humidity.

Results: The best formulations retained nearly 80% of added vitamin A even after 24 weeks at 45°C and 60% humidity. This was better and cheaper than the original Ultra Rice formulation and included only *Codex Alimentarius*-compliant ingredients.

Rief D. ***Comparative Stability Study Using Colombian Fortified Premix*** **[unpublished report]. Minneapolis, Minnesota: Medallion Laboratories; 2004.**

Objective: A storage study was conducted in order to determine the stability over time of the original vitamin A premix manufactured in Colombia (now abandoned), and therefore to determine whether the micronutrient overages used for production were adequate.

Methods: Samples from a single production lot were collected and separated into two different batches. Each batch was separated into six individual lots. One batch was sent to the laboratory for frozen storage, and the second batch was stored at ambient temperature in the Bogota warehouse. Over a period of 9 months, the samples in Bogota were sent to the laboratory. After receiving the product from Colombia, the lab pulled the frozen product, and both samples were subjected to the same micronutrient analysis.

Results: Micronutrient levels over the 9-month period varied depending on whether the samples were stored under frozen or ambient conditions. Frozen samples showed a loss of ~25% vitamin A, 20% folic acid, and no losses of zinc or vitamin E. Results for thiamin were inconclusive, likely due to incorrect measurement of the micronutrient during the production run. Samples stored under ambient conditions showed a loss of ~95% vitamin A, 15% folic acid, 20% vitamin E, and no loss of zinc.

Based on the conclusions of the study, the Ultra Rice team was able to make formulation recommendations to the Colombian manufacturer that would improve the stability of the product. Zinc is clearly stable over a 9-month period, regardless of how the premix is stored. Vitamin E is stable for 9 months if the premix is frozen, but appears to begin to oxidize after about 4 months on the shelf. Losses of folic acid were comparable under both storage conditions. However, increasing the overage of folic acid in the formulation by an additional 5% to 10% would ensure that label claims could be met. Finally, vitamin A was very unstable under ambient conditions, with only 30% remaining after a single month's storage. The vitamin A results from this real-world study support the results obtained from the vitamin A reformulation study conducted by L. Diosady (2003).

Diosady L, Li OY. ***Phase 1 Report on the Development and Stability Testing of an Iron-Containing Formulation of Ultra Rice*** **[unpublished report]. Toronto, Canada: Food BioTek Corporation; 2004.**

Diosady L, Li OY. ***Final Report on Development and Stability Testing of an Iron-Containing Formulation of Ultra Rice*** **[unpublished report]. Toronto, Canada: Food BioTek Corporation; 2005.**

Objective: To develop an Ultra Rice formulation that maintains its color and iron bioavailability, as well as most of its vitamin B activity, over the normal shelf life of Ultra Rice.

Method: Phase 1 of the project involved reviewing scientific literature and international food regulations related to appropriate iron fortificants and stabilizers, standardizing production equipment and analytical methodology, and making formulation recommendations for Phase 2.

Phase 2 involved formulation of 16 different batches of manufactured rice grains containing iron, zinc, vitamin B1 (thiamin), folic acid, and niacin. Four different iron compounds (sodium iron EDTA, SunActive® iron [a micronized and encapsulated ferric pyrophosphate], standard ferric pyrophosphate, and coated ferrous fumarate) and four different antioxidant combinations were included in the study. Batches were stored at three different temperature/humidity conditions (22°C/50%–70% RH, 40°C/60% RH, and 40°C/100% RH). Samples were examined each 6 to 8 weeks and analyzed for micronutrient content, color, and rancidity.

Results: Virtually all of the iron, zinc, folic acid, and niacin were retained in all of the formulations for 6 months, regardless of the study conditions. Vitamin B1 was generally stable during 6 months of storage, with several formulations retaining 95% or more vitamin B1, even under tropical conditions.

All formulations developed some rancidity over time, as measured by the peroxide value, particularly samples stored at higher temperature and higher humidity. Formulations containing NaFeEDTA experienced the greatest rancidity problem, followed by samples containing coated ferrous fumarate. Formulations containing ferric pyrophosphate or SunActive® iron produced insignificant rancidity. The particular antioxidant combination used in the current Ultra Rice formulation appeared to provide superior protection against peroxidation for samples containing ferric pyrophosphate, SunActive® iron, or coated ferrous fumarate, even under tropical conditions.

The intensity of color changes over a 3-month period were determined using Hunter L*a*b* values. Although all formulations changed somewhat over time, the change was minimal, even at higher temperature and relative humidity. As expected, the darkest samples contained ferrous fumarate and the lightest samples contained ferric pyrophosphate compounds.

Conclusions: Iron source and storage condition had little effect on the stability of iron, zinc, or B vitamins included in a multiple-micronutrient fortified Ultra Rice premix over a period of 6 months. Iron did have an effect on rancidity, but formulations containing ferric pyrophosphate compounds showed very little evidence of rancidity, even under severe storage conditions. This study showed that it is technically feasible to produce an Ultra Rice premix with a good shelf life combining several B vitamins, iron, and zinc. The current Ultra Rice formulation possesses good micronutrient stability and undergoes minimal changes in color and flavor, even under harsh environmental conditions, for periods up to 6 months.

Bioavailability

Flores H, Guerra NB, Cavalcanti ACA, Campos FACS, Azevedo MCNA, Silva MBM. Bioavailability of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1994;59(2):371–372, 377.

Author affiliation: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco, Recife, Brazil.

Method: The Relative Dose Response (RDR) test was used to assess the bioavailability of vitamin A in a stabilized form in artificially produced rice kernels. The nutrified rice, cooked with sugar and milk, was offered to 83 deprived children as the challenge dose for an RDR test.

Results: The children showed positive and negative tests in agreement with their serum retinol levels. The regression of RDR on serum retinol levels was the same as that observed when the conventional RDR test was applied. The fact that deficient subjects showed a serum retinol reaction in a five-hour period indicates that the retinol in Ultra Rice was absorbed and transported.

Hunt JR. *Assessment of the Bioavailability of Ferric Pyrophosphate in Ultra Rice Using the AOAC Rat Hemoglobin Repletion Method* [unpublished report]. Grand Forks, North Dakota: USDA-ARS Grand Forks Human Nutrition Research Center; 2003.

Objective: To determine the bioavailability of iron from four ferric pyrophosphate compounds, relative to ferrous sulfate, using the AOAC Rat Hemoglobin Repletion Method.

Method: Following a depletion period of 24 days consisting of a low-iron diet, rats were weighed and their hemoglobin levels were measured. The rats were fed iron-fortified diets for 14 days. Nineteen different dietary treatment groups were included, with varying levels of each of the ferric pyrophosphate compounds. Following the repletion period, rats were again weighed and their hemoglobin levels were measured.

Results: Hemoglobin repletion data were analyzed by the slope ratio assay method, expressing bioavailability relative to ferrous sulfate. SunActive® iron was more bioavailable than the other ferric pyrophosphate compounds for correcting the iron deficiency of anemic rats (92%–94% RBV). The bioavailability of the other ferric pyrophosphate compounds was approximately 70%–75% RBV.

Conclusions: Using the rat model, SunActive® iron is nearly as bioavailable as ferrous sulfate and is significantly more bioavailable than any of the other forms of ferric pyrophosphate tested. Micronization, with or without encapsulation, did not increase bioavailability significantly relative to standard ferric pyrophosphate (other than SunActive®).

Efficacy

Flores H, Campos FACS, Silva MBM, Lins MH, Barretto E, Albuquerque S. *Efficacy of Vitamin A Enriched Rice in the Treatment and Prevention of Vitamin A Deficiency* [unpublished report]. Recife, Brazil: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco; 1994.

Method: The biological efficacy of vitamin A-enriched rice was pilot-tested in Brazil in children aged 11–77 months. Eighty-three children were fed the fortified rice (1500 IU per 100-g serving) for 30 days, using as assessment criteria the frequency distribution of serum retinol levels.

Results: The mean serum retinol level increased from 1.09±0.40 to 1.65±0.51 umol/L. At baseline, 51% of the children presented with levels below the proposed cut-off point of 1.05 umol/L, compared to 8.8% at endpoint.

Haskell MJ, Pandey P, Graham JM, Peerson JM, Shrestha RK, Brown KH. Recovery from impaired dark adaptation in nightblind pregnant Nepali women who receive small daily doses of vitamin A as amaranth leaves, carrots, goat liver, vitamin A-fortified rice, or retinyl palmitate *American Journal of Clinical Nutrition.* 2005;81:461–71.
Study initiated 2000; completed 2003.

Author affiliation: Program in International Nutrition, Department of Nutrition, University of California-Davis, USA; Nepali Technical Assistance Group, Kathmandu, Nepal.

The purpose of this study was to assess the effect of daily supplementation with small doses of vitamin A as either preformed retinol or beta-carotene from food sources or as retinyl palmitate on dark adaptation and plasma retinol concentrations in pregnant nightblind (XN) women. XN pregnant women were randomly assigned to one of six treatment groups to receive for 6 days/week for a period of 6 weeks either 0.850 mg retinol equivalents (RE) per day as (1) retinyl palmitate, (2) vitamin A-fortified Ultra Rice, (3) liver, (4) green leafy vegetables, (5) carrots, or (6) 2.0 mg RE/d as retinyl palmitate. Plasma retinol concentrations were measured before and after the intervention period. Dark adaptation was assessed weekly by measurement of the pupillary response threshold. These outcomes were also measured in a comparison group of non-XN, pregnant women. The mean initial and final plasma retinol concentrations of XN women were 0.96±0.05 and 1.07±0.05 umol/L ($p<0.0001$), respectively. The mean initial and final pupillary thresholds of XN women were -0.71±0.06 log cd/m^2 and -1.42±0.06 log cd/m^2, respectively ($p<0.0001$) (proposed cut-off for normal is -1.1).

The final mean pupillary threshold of XN women was similar to the value for the non-XN women and U.S. women (-1.43 and -1.35 log cd/m^2). Recovery from impaired dark adaptation did not differ among women who received 0.850 mg RE/d as liver, Ultra Rice, green leafy vegetables, carrots, or as a vitamin A capsule. The mean adjusted pupillary threshold (a measure of dark adaptation, in turn influenced by vitamin A status) improved from a mean of -0.7 at baseline to -1.3 after 7 weeks in the Ultra Rice group. Since the leafy and carrot groups were the only ones to increase in carotenes that are high in those foods, it is highly unlikely that confounders could explain the improvements in dark adaptation seen in all groups, including the one fed Ultra Rice.

The Ultra Rice formulation used in this trial contained α-tocopherol as an antioxidant (currently excluded, but only for cost reasons), and the Ultra Rice group improved more in serum α-tocopherol levels than all the other groups (the final value was statistically significantly greater than two of the other groups).

Effectiveness

Flores H, Campos FACS, Silva MBM, Lins MH, Barretto E, Albuquerque S. *Efficacy of Vitamin A Enriched Rice in the Treatment and Prevention of Vitamin A Deficiency* [unpublished report]. Recife, Brazil: Department of Nutrition, Center of Health Sciences, Federal University of Pernambuco; 1994.

Method: The effectiveness of including vitamin A-fortified rice in the normal food given to children at preschools was tested in Brazil. Six randomly selected municipal day care centers with 415 children aged 7.7–83.6 months were included. At baseline, and then at four-month intervals, fasting blood samples were taken to determine serum retinol. At the baseline and 12-month evaluations, the children underwent a Relative Dose Response (RDR) test.

Results: Feeding fortified rice for one year improved the vitamin A status, as assessed by serum retinol levels. Serum retinol values continually increased at each of the four-monthly measurements up to one year of age. After a full year, no children were deficient according to the relative dose response test, compared to 44% at baseline. There were no major differences in children in these experimental preschools compared to children in nearby preschools in diet or growth during the study year. There were only slight differences in morbidity (mainly in favor of the Ultra Rice group). Thus the time required to revert vitamin A deficiency status to normality, feeding a small daily dose of vitamin A (close to the safe recommended intake), can be estimated to be about one year.

Sensory Evaluation

Flores H, Guerra NB, Cavalcanti ACA, Campos FACS, Azevedo MCNA, Silva MBM. Bioavailability of vitamin A in a synthetic rice premix. *Journal of Food Science*. 1994;59(2):371–372, 377.

Method: Rice fortified with Ultra Rice premix was tested by trained food panelists according to the method of Larmond (1970).

Results: Panelists found that the fortified rice had the same sensory characteristics of ordinary rice. They preferred the taste of the fortified rice.

Hermana H. *Acceptability Test of Ultra Rice* [unpublished report]. Bogor, Indonesia: Nutrition Research and Development Centre, National Institute for Health Research and Development, Ministry of Health; 1995.

Cori H. ***Report on Experience in Multiple Fortification of Rice through the Simile Grain Technology (Ultra Rice)*** **[unpublished report]. Santiago, Chile: F. Hoffmann-La Roche, Latin American Regional Center; 1999.**

Bett-Garber KL, Champagne ET, Ingram DA, Grimm CC. Impact of iron source and concentration on rice flavor using a simulated rice kernel micronutrient delivery system. ***Cereal Chemistry*****. 2004;81:384–388.** *Based on research done in 2001.*

Author affiliation: Southern Regional Research Center, Agricultural Research Service, United States Department of Agriculture; New Orleans, Louisiana.

Objective: Determine how differing sources of iron impact the effect of Ultra Rice on the flavor of milled rice, as determined by descriptive analysis.

Methods: An extruded grain designed to look like a rice kernel fortified with one of two sources of iron (elemental iron and $FeSO_4$), zinc, thiamin, and folic acid was mixed with milled Calrose rice at ratios of 1:50, 1:100, and 1:200. Twelve panelists previously trained in the principles and concepts of descriptive analysis participated. The rice lexicon used included 12 unique flavor attributes. Flavor was determined by smelling and by evaluation in the mouth. Intensity was rated using a 0–15 anchored universal intensity scale. Each sample was presented to the panelists twice, in separate sessions, following a randomized design in which each session consisted of three samples, a "standard," and a blind control.

Results: The intensities of water-like, sour taste, hay-like musty, and alfalfa/grassy/green bean flavors were enhanced by the addition of ferrous sulfate, ferrous sulfate plus multiple fortificants, and multiple fortificants without iron at the highest concentration (1:50 ratio). Astringent mouthfeel was affected by addition of ferrous sulfate and ferrous sulfate plus multiple fortificants. Elemental iron with multiple fortificants affected the flavor of the base rice less. However, these results gave no indication of consumer preference.

Indian Market Research Bureau International (IMRB). ***Potential Introduction of Ultra Rice in India: Complete Market Assessment*** **[report prepared for PATH]. New Delhi: IMRB; 2003.**

Objective: To gauge the organoleptic acceptance of Ultra Rice fortified with ferrous sulfate and the sensitivity of potential target segments.

Method: Cooked, multi-micronutrient fortified rice was presented to 600 consumers in a taste test carried out with 6 samples: (1) rice fortified 1:100 (1/3 RDA), (2) rice fortified 1:200 (1/6 RDA), (3) rice with no fortification, (4) rice fortified 1/3 RDA with mild curd sauce, (5) rice fortified 1/6 RDA with mild curd sauce, and (6) rice with no fortification with mild curd sauce. Raw rice was used with 300 urban consumers and parboiled rice with 300 rural consumers. Samples were presented "blind" in rotating order. Consumers were stratified by socioeconomic status and age. Consumers ranked 2–3 tablespoons of each sample on a five-point scale on smell, taste, aftertaste, similarity to normal rice, and overall liking.

Results: In general, consumers were unable to sense any difference between fortified and regular rice, liked them equally well, and were equally willing to purchase them. The slightly gray color of the kernels (fortified with ferrous sulfate—no longer used in Ultra Rice) was disliked by some consumers, but only 7% of consumers could sense an aftertaste from the 1:100 blend. After the advantages of fortified rice were explained to the consumers, purchase intention increased, more so for the lower income groups.

Consultor Apoyo. *Ultra Rice Organoleptic Tests in Ecuador* [unpublished report]. Quito, Ecuador: Consultor Apoyo; 2003.

Objective: To evaluate consumer acceptance and preference of unfortified rice, rice blended with sodium iron EDTA-fortified Ultra Rice, and rice blended with ferric pyrophosphate-fortified Ultra Rice.

Method: Two premixes were included in the study, each designed to deliver 6 mg iron, 3 mg zinc, 0.4 mg vitamin B1 (thiamin), and 0.2 mg folic acid per 100-g serving: (1) Ultra Rice 1, containing sodium iron EDTA as the iron source, and (2) Ultra Rice 2, containing SunActive® ferric pyrophosphate as the iron source.

Consumers assessed both raw and cooked rice to evaluate appearance (color, size, shape, cleanliness), taste (sweet, sour, acrid, after-flavor), and aroma. Consumers were also asked to evaluate the general concept of fortified rice and intent to purchase. A total of 419 interviews were conducted on approximately equal samples of women homemakers in four areas of the country, covering highlands, coast, rural, and urban areas of Ecuador.

Results: Most consumers wash rice two to three times before cooking it. Sixty-nine percent use and discard excess water in cooking. Eleven percent did not like the cooked plain rice, 27% did not like Ultra Rice 2, and 43% disliked Ultra Rice 1. Thirty-nine percent felt the plain rice was different than the rice they normally used, compared to 64% for Ultra Rice 2 and 69% for Ultra Rice 1. In general, traditional non-fortified rice was preferred over fortified rice. Between the two fortified rice samples, Ultra Rice 2 was preferred over Ultra Rice 1. The concept of fortified rice was considered to be important among those surveyed, and respondents said they would buy it if available (4.3 on a five-point "intent to purchase" scale).

Cost

PATH. *Feasibility of Introduction of Vitamin A-Fortified Rice in Indonesia* [report to the Micronutrient Initiative]. Jakarta, Indonesia: PATH; 1997. *Research done 1994–1996.*

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