Understanding Factors that Influence the Benefits and Costs of Rice Fortification

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Key Messages

- Fortified staple crops are one of many alternative programs for addressing micronutrient deficiencies in developing countries. Their effectiveness will depend, in part, on the measure of impact selected, and on the diets of target beneficiaries, which can vary spatially and across socioeconomic groups. Their costs will depend on the fortification technologies selected and the scales at which they are undertaken.
- This paper uses detailed dietary intake data from Cameroon to demonstrate the effects of alternative definitions of "success" on predicted program impact.
- This paper also reports cost estimates for medium-scale production of fortified rice kernels in the Dominican Republic and discusses various economic considerations for scaling up rice fortification
- Twin-screw, hot-extrusion technology already exists in the country on both large and medium scales. Based on established medium-scale production technologies, the estimated average cost of producing fortified rice kernels is US$1.76 per kg. Based in rice consumption habits in the Dominican Republic, rice fortification appears to be a good bet for increasing micronutrient intake.
- However some measures of impact (e.g., effective coverage) may suggest that programs other than rice fortification be pursued, perhaps subnationally.
- Regardless of micronutrient intervention program choices, fully funded monitoring and evaluation data collection and analyses will be required.
- Rice fortification has not yet begun in the Dominican Republic and private companies that are set to produce fortified rice kernels are in various stages of trials, and government regulations regarding premixes are still under development.
- Regardless of eventual regulations and despite very high average per capita rice consumption in the Dominican Republic, in this relatively small country excess national capacity for producing fortified rice kernels will likely emerge; underutilized capacity may complicate emerging public/private partnerships and may also increase the cost of a national rice fortification program.

Introduction

Vitamin and mineral (micronutrient [MN]) deficiencies are common in developing and low-income countries, especially among young children and women of reproductive age (WRA) because of their relatively high MN requirements.[1,2,3] The economic consequences can be large,[4,5] and addressing these MN deficiencies is expected to be very cost-effective.[6] Sets of best-bet MN intervention programs have been identified,[7] though gaps in knowledge remain regarding their effectiveness and cost-effectiveness subnationally and over time.[8]

At country level, several choices have to be made before selecting the appropriate MN intervention programs. First, measures of impact must be selected and agreed upon. There are many candidates available, chief among them being:[9]

- **Reach:** the number (or %) of individuals who receive the benefits of a program, regardless of their individual needs or the amounts of MN received;
- **Coverage:** the number (or %) of individuals with micronutrient deficiency who receive the benefits of the program, regardless of the amounts of MN received; and
- **Effective coverage:** the number (or %) of individuals *with insufficient dietary intake who achieve adequate dietary intake* due to program intervention(s).

Different measures of impact will often point to different combinations of cost-effective interventions.

> "First, measures of impact must be selected and agreed upon"

Second, the target beneficiary group or groups should be identified; different groups (e.g., young children versus WRA) may have different MN needs and consume different amounts of different types of foods, therefore one would not expect that food fortification programs would affect all individuals equally.

Third, even in small countries, MN deficiencies might not be distributed uniformly over the landscape; if there are regional differences in needs (north versus south, urban versus rural) and if programmatic options exist, decision-makers may be in a position to choose where to intervene.

Finally, timing often matters in responding to MN deficiencies; some programs are quicker to launch but less cost-effective in the long term, others will require longer start-up periods but may prove to be more cost-effective in the long term. Therefore, combinations of programs that phase in/out over time may be required to deal with pressing MN deficiency issues; developing such a strategy requires a long planning horizon.

This paper touches on the first three of these issues. The next section uses a nutrition benefits model based on nationally representative, individual dietary intake data from Cameroon to demonstrate the differences among indicators of MN intervention program impacts. Section three uses the same model to assess the effects on WRA of the hypothetical rice fortification program in three separate macro-regions of Cameroon. Section four examines the costs of rice fortification in the Dominican Republic using medium-scale, hot-extrusion technology, and assesses national fortified rice kernel production capacity. Section five provides conclusions and some policy implications.

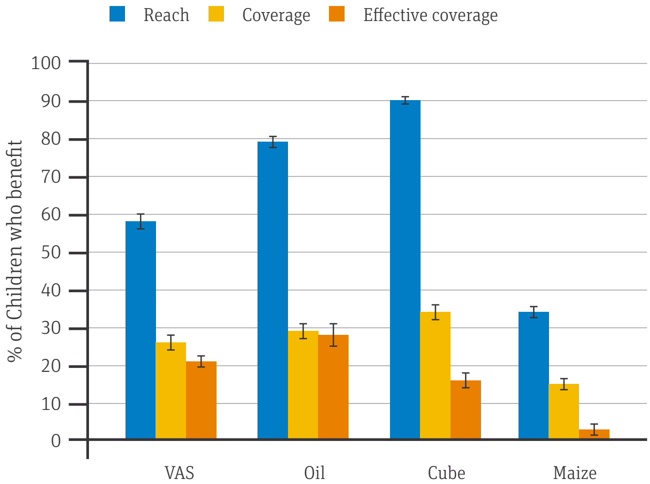
Alternative measures of impact of a MN intervention program

Different measures of impact can yield very different answers to the question "How successful are current/planned MN intervention programs?" **Figure 1** reports estimates generated by the Micronutrient Intervention Modeling Project's (MINIMOD) nutrition benefits model[9] of the reach, coverage, and effective coverage of four alternative platforms for delivering vitamin A (VA) to young children in urban areas in Cameroon: high-dose VA supplementation (VAS) delivered via Child Health Days, fortified edible oils (Oil) and bouillon cubes (Cube) delivered via commercial outlets, and biofortified Maize.[9,10] If simply reaching target beneficiaries is the selected measure of impact, then bouillon cubes, which were consumed by nearly 95% of surveyed individuals on the previous day, is the clear "winner." If reaching only those with VA deficiency is the impact measure, then fortified bouillon cubes, oil and VAS become close competitors, all with measures of predicted impact below 50%. Finally, if the objective is raising the dietary intake of VA among individuals with low intake to adequate VA intake is the objective – i.e., if effective coverage is selected as the impact measure – then fortified oil and VAS are clearly the superior MN intervention programs in this setting, for the program parameters modeled (reach and fortification levels), and for this beneficiary group, but each of these programs fails to reach a large percentage of children in need, signaling the importance of selecting combinations of programs to more completely address VA deficiencies.

Predicting the impacts of fortified rice in Cameroon

Because diets vary spatially and across socioeconomic groups, one would expect that patterns of effects of MN intervention programs would also vary across these dimensions. **Figure 2** shows estimated effects of the hypothetical introduction of fortified rice into the diets of WRA in Cameroon (assuming that 5.9 mg/kg of vitamin A and 95 mg/kg of zinc were added to 100% of rice consumed). The first trio of columns reports the reach of fortified rice; fewer WRA in the South macro-region of Cameroon consume rice, compared to those in the North and City macro-regions, and hence, on average, WRA in the South benefit less from this MN intervention program. Perhaps more

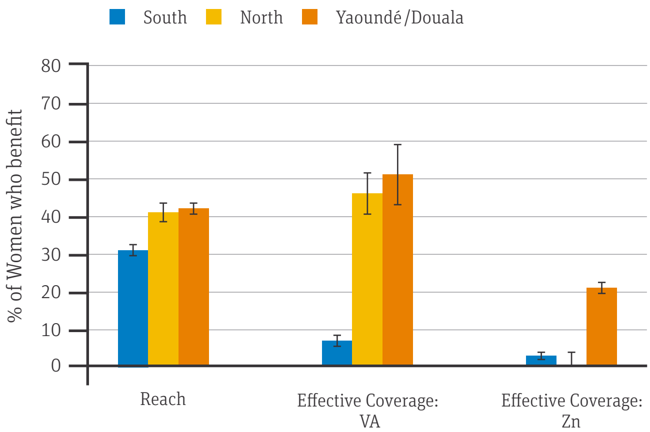
FIGURE 1: Predicted reach, coverage, and effective coverage of alternative vitamin A delivery platforms*: Urban children, 6–59 months of age, Cameroon



*Example data for vitamin A programs delivered to children 6–59 months of age in Yaoundé/Douala (2009). VAS represents high-dose VA supplementation provided via Child Health Day national campaigns. Oil, cube, and maize represent, respectively, fortified edible oil, fortified bouillon cubes, and biofortified maize. Oil assumes measured fortification values (44% target). Cube and Maize assume 100% (bio)fortified.

Source: MINIMOD Project Data, authors' calculations.

FIGURE 2: Predicted effects of rice fortification with VA and zinc*: Women in Cameroon, by macro-region, and by measure of program impact



*Assumes 5.9 mg/kg of vitamin A and 95 mg/kg of zinc were added to rice;[23] 100% of consumed rice is assumed to be fortified in this very optimistic scenario.

Source: MINIMOD Project Data, authors' calculations.

importantly, the second and third trios of columns report effective coverage for VA and for absorbable zinc. Because of inter-macro-regional differences in diets and especially in VA and zinc intakes, WRA in the major cities are predicted to benefit much more from a rice fortification program than their counterparts in the South.

The rice fortification capacity and cost in the Dominican Republic

While several technologies exist for the fortification of rice,[11] not all technologies are appropriate for all developing countries, for both cultural and economic reasons. In the Dominican Republic, as in many developing countries, consumers at all socio-economic levels carefully select out imperfect rice grains and practice intensive rice washing prior to cooking.[12] Therefore, extrusion is likely to be the most viable technology for introducing and preserving adequate levels of micronutrients into rice, as well as for preserving the color and taste of rice that consumers recognize and demand.[12,13] Typically, the high cost of establishment and operation is a barrier to rice fortification via hot extrusion.[14] However, in recent years in the Dominican Republic, private industry has invested in hot-extrusion technology on both large and medium scales. This section explores the estimated costs of medium-scale rice fortification using hot-extrusion technology, and the various economic considerations for scaling up rice fortification using this technology in the Dominican Republic.

"While several technologies exist for the fortification of rice, not all technologies are appropriate for all developing countries"

Two rice-processing companies have purchased and installed twin-screw hot-extrusion machines, a technology that has been shown to produce reconstituted grains with "superior integrity, flavor, and texture" compared to other types of extrusion or fortification technologies.[15] One company is classified in this paper as a large-scale producer of extruded rice kernels, and the other is classified as a medium-scale producer of the same product. While somewhat arbitrary, the scale distinction used here is based on the type of extrusion technology available at each facility in terms of cost of the extruders and productive capacity (see **Table 1**).

Using average annual rice consumption in the Dominican Republic[16] and assuming a 1:200 fortified-to-non-fortified rice kernel blend,[13,17] the annual national requirements for fortified rice kernels is approximately 2,700 metric tons. Installed medium-scale extrusion technology could meet national demand in approximately one year; installed large-scale technology could do so in about three months. The micronutrient specifications for the Dominican Republic are still under development by the Ministry of Public Health in collaboration with USAID, DSM, regional partners, and other international nutrition research

TABLE 1: Productive capacity of established rice extruders in the Dominican Republic (metric tons of extruded kernels/month)

Medium-Scale *	Large-Scale
240	1,200

* Production capacity of the medium-scale technology is based on running four of five extruders, five days per week, 20 hours per day.

Source: Authors' calculations based on data provided by rice kernel producer.

entities.[13,18] Once these specifications are set, the MN premix for rice kernel extruders will be produced, and producers will fine-tune extruders to guarantee the production of fortified rice kernels that will be essentially indistinguishable by consumers from common grains of rice.

The estimated cost of rice fortification presented below is based on data from a medium-scale hot-extrusion production technology. These data are based on actual establishment costs and expected operational costs. **Tables 2** and **3** provide a summary of estimated costs. The largest drivers of annual input costs are electricity and broken rice (the key input into the extrusion process), which constitute approximately 22% each, and the fortified premix, which constitutes almost 52% of the annual recurring costs.

There are additional private-sector costs not included in this calculation that should be considered. Specifically, private-sector costs of blending and packaging fortified kernels with non-fortified rice kernels are not considered here. If mandatory rice fortification is introduced, small-scale rice millers that lack the technology to produce fortified rice kernels would be required to purchase fortified kernels and the machines to blend them with non-fortified milled rice. Machinery and blending costs are expected to be small and diffused across a large number of rice millers. The cost of fortified rice kernels, on the other hand, could significantly increase overall input costs for all rice millers, especially those engaged in the processing and marketing of lower-quality, broken-grain rice.

Perhaps more important, the public-sector costs associated with managing the rice fortification program, including monitoring of the quality of rice in the wholesale and retail markets, are not addressed here.

> "Given the quantities of rice consumed by all segments of the population in the Dominican Republic, rice fortification is one likely cost-effective delivery platform for addressing MN deficiencies"

Conclusions and implications for policy

Given the quantities of rice consumed by all segments of the population in the Dominican Republic, rice fortification is one likely cost-effective delivery platform for addressing MN deficiencies. However, several important caveats apply.

First, while fortified rice may be an excellent platform for reaching targeted beneficiaries, it may not deliver sufficient

TABLE 2: Annual costs of producing fortified rice kernels using medium-scale technology in the Dominican Republic (thousands US$[a])

Principle and Interest on Establishment Costs[b] (Includes machines, new buildings/structures, 5.5% compound annual interest)	US$219
Annual Plant Operational Costs[c] (Includes labor, electricity, maintenance/repairs, quality control)	US$1,163
Annual Input Costs (Includes broken rice, vitamin and mineral premix)	US$3,692
Total Annual Costs[d] (Excludes blending, packaging, public sector costs)	**US$5,074**

[a] 2016 US$

[b] Assume a 5.5% compound annual interest rate and an expected life of extruders and buildings of approximately 10 years according to private industry estimates.

[c] Production capacity of the medium-scale technology is based on running four of five extruders, five days per week, 20 hours per day.

[d] Based on 2,880 MT annual production. Excludes private-sector blending costs, and public sector program management and M&E costs.

Source: Authors' calculations based on data provided by medium-scale producer during factory visits.

A little Guatemalan girl, 2012

amounts of specific MN to achieve dietary intake targets, especially for young children who have high MN needs relative to their total food intake.

Second, therefore, combinations of MN interventions may be required to achieve overall MN program objectives, and some of these interventions may need to be targeted to specific socioeconomic groups and/or specific regions.[21] Special attention may need to be paid to the rural poor, who tend to consume own-produced, and hence unfortified, rice.[22]

Third, a mandatory rice fortification program will increase the price of rice; which stakeholder groups in society pay this increased price is a policy choice. One option is to pass some or all cost increases on to consumers; given that some of the benefits of rice fortification will accrue to consumers, it is reasonable that they should bear some of the costs. However, the public sector will also likely benefit from rice fortification via, for instance, reduced public healthcare costs, and therefore should shoulder part of the cost. Finally, the various subsectors of the rice economy, including importers, may also be called upon to cover some of the rice fortification program costs. In the end, and as always, identifying which groups in society cover program costs will be a negotiated outcome, and one that should be revisited periodically.

Fourth, installed hot-extrusion capacity in the Dominican Republic already exceeds estimated annual national needs for fortified rice kernel production. Underutilized capacity could raise the cost of nationally produced fortified kernels as well as undermine incentives to invest in extrusion capacity. International sources of fortified rice kernels also exist. Therefore, one key element of the national rice fortification strategy will be to determine the source(s) of fortified kernels, the prices to be paid for them and by whom, and the contractual arrangements linking producers of fortified kernels, downstream millers, and segments of the public sector charged with managing and overseeing the fortification program.

Finally, collecting and analyzing the dietary intake and biomarker data required to monitor, evaluate, and adjust the rice fortification and other MN programs should be a well-funded element of any national MN strategy, and should be put in place before programs are launched.

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TABLE 3: Cost to private industry of producing fortified rice kernels using medium-scale technology (US$[a])

Total Establishment Cost of Capital Investments	**US$1,715,860**
(Includes machines, new buildings/structures, labor and electricity for installation and testing)	
Estimated Cost per MT of Fortified Rice Kernels [b]	US$1,762
($5,074,000/year ÷ 2,880 MT/year)	
Cost to Meet Annual National Estimated Fortified Rice Kernel Needs	US$4,757,400
($1,762/MT* 2,700 MT/year)	

[a] 2016 US$

[b] Our estimate of $1.76 US$/kg of fortified rice kernels includes the cost of broken rice as the key input, and falls within the range of costs estimated by other authors, e.g., DSM estimates are $4.10 US$/kg of fortified rice kernels for a premix formulated to address anemia and $2.10 US$/kg of fortified rice kernels for an alternative premix, and Alavi et al. provide an estimate of $1.19 US$/kg of fortified rice kernels.

Source: Authors' calculations based on data provided by medium-scale producer during factory visits.

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