EMBEDDING NUTRITION IN THE RICE VALUE CHAIN IN BANGLADESH

September 2016

The findings in this paper are from the full report 'Embedding Nutrition in the Rice Value Chain in Bangladesh: A Review and Assessment of Intervention Opportunities'. This full report was commissioned by the Global Alliance for Improved Nutrition (GAIN) and prepared under the supervision of Bonnie McClafferty. Field support was provided by Basanta Kar and Moniruzzaman Bipul. USAID generously financed this research and the report findings benefited from the substantive counsel of the USAID Bangladesh Food Security and Health team. The report also benefited from the extensive input of Dr Christine Hotz of Nutridemics (Toronto) who oversaw the nutritional research and nutritional impact measurement aspects in collaboration with lab work conducted by Khandaker Aminul Kabir of the Bangladesh Rice Research Institute and field research supported by Matrix Consulting (Dhaka).

This report was compiled by Hannah Guedenet. The findings in the report were prepared by Dalberg Global Development Advisors under the leadership of Yana Watson Kakar, Michael Tsan and Shyam Sundaram with support from a global team of researchers, writers and editors including Bhavana Chilukuri, Kanishka Bhattacharya, Swetha Totapally, Pallavi Jayannavar and Simon Clark. As part of this assignment, Dalberg also oversaw extensive market research across the rice value chain and rice consumers executed by Young Consultants and Sirius Market Research.

For further information on this report, please contact Bonnie McClafferty, Director of Agriculture and Nutrition Security at GAIN, at b.mcclafferty@gainhealth.org.

Suggested citation: GAIN, Dalberg Global Development Advisors, U.S. Agency for International Development. 2016. *Embedding Nutrition in the Rice Value Chain in Bangladesh.* GAIN Working Paper. Geneva: GAIN.

DISCLAIMER

TABLE OF CONTENTS

ABSTRACT

Numerous rice value chain studies have been conducted over the years, but few focus specifically on how rice can be used as a vehicle to promote nutrition. In 2012–2013, with the support of the U.S. Agency for International Development (USAID) and its national and global partners, the Global Alliance for Improved Nutrition (GAIN) engaged in a series of comprehensive technical and market feasibility studies in Bangladesh to explore how modifications in rice cultivation and processing could improve the nutritional density of rice. Given the widespread deficiency of zinc in Bangladesh, and the lack of national prevention programs, this work focused specifically on increasing the zinc content of the rice grain. The findings from these studies suggest that there is a portfolio of options that can and should be considered as part of an agriculture-nutrition strategy in Bangladesh. Fortificant soaking (i.e. adding zinc fortificant to soaking water during the parboiling process) presents the most convincing way to embed nutrition into the agricultural rice value chain, as it has a high potential to improve nutritional impact across a range of rice varieties. Reduced milling could be considered an additive concept as it is not a technically complex idea, but it has limited nutritional impact. Zinc fertiliser offers interesting opportunities to improve nutritional outcomes, primarily in rural areas, and is highly cost-effective. Our research confirmed that parboiling conditions, which may result in larger amounts of some nutrients being transferred into the rice grain, have a negligible effect on increasing rice zinc content. Each concept has its merits and challenges, and, depending on the resources and timeline available, multiple concepts can be pursued in parallel with each other, with the potential to improve the health and livelihoods of a significant proportion of the Bangladesh population suffering from micronutrient malnutrition.

LIST OF ACRONYMS

BADC	Bangladesh Agriculture Development Corporation
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
BSTI	Bangladesh Standards and Testing Institute
DAP	Diammonium phosphate
DoM	Degree of milling
GAIN	Global Alliance for Improved Nutrition
IFDC	International Fertiliser Development Centre
IZA	International Zinc Association
IZiNCG	International Zinc Nutrition Consultative Group
µg	Microgram
MoP	Muriate of potash
NGO	Non-governmental organisation
NPNL	Non-pregnant, non-lactating women
SRDI	Soil Resource Development Institute
Tk	Bangladeshi taka
TSP	Triple super-phosphate
WFP	World Food Programme

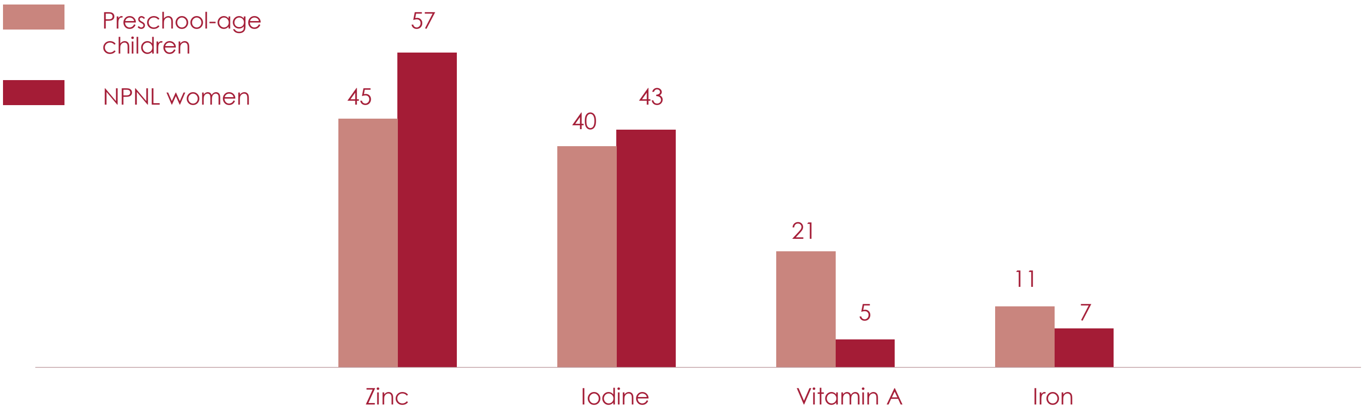
1. MICRONUTRIENT MALNUTRITION CHALLENGE IN BANGLADESH

Micronutrient malnutrition results from consistently consuming foods that may have high energy or caloric content but are lacking in essential vitamins and minerals, particularly vitamin A, iron, iodine, and zinc. Without these vitamins and minerals, humans are unable to reach their full physical, mental, and cognitive potential. Poor-quality diets are themselves a result of larger structural factors, such as agro-ecological conditions and poverty that make it difficult to grow or afford micronutrient-rich foods. A lack of awareness regarding the importance of nutrition and traditional food preparation and consumption patterns that decrease nutrient retention also contributes to micronutrient malnutrition.

Micronutrient malnutrition results in an estimated US$1 billion loss in economic productivity in Bangladesh on an annual basis (Embassy of the United States of America, Dhaka, 2012). This is a significant cost to the Bangladeshi economy — equivalent to 0.8% of GDP in 2012. Micronutrient malnutrition can lead to lower educational capacity because it limits cognitive development, which adversely affects an individual's ability to capitalise on opportunities for skilled work. It also results in poor physical development and low energy, which reduce the ability of an individual to engage in manual labour, a major source of employment in Bangladesh. Compounded year-on-year, US$1 billion in lost productivity stemming from lower mental and physical capacity will significantly affect Bangladesh's growth trajectory.

In Bangladesh, zinc, iodine, and vitamin A deficiencies are major contributors to micronutrient malnutrition, while there is mixed evidence on the severity of iron deficiency (icddr,b et al., 2013). As Figure 1 shows, zinc deficiency is the greatest contributor to micronutrient malnutrition in Bangladesh, affecting almost half of all preschool-age children and over half of non-pregnant, non-lactating (NPNL) women. Iodine deficiency is also substantial, affecting over 40% of preschool-age children and NPNL women. Vitamin A deficiency is less severe, affecting 21% of preschool-age children and roughly 5% of NPNL women. Data on iron deficiency are less clear. According to the *National Micronutrient Status Survey* conducted in 2011–2012, the prevalence of iron deficiency is substantially lower than that of other micronutrient deficiencies (about 11% for preschool-age children and 7% for NPNL women). These low levels have been attributed to bioavailable iron-rich groundwater being the main source of drinking water for 80% of the Bangladeshi population (icddr,b et al., 2013). However, according to a national anaemia survey conducted in 2004 by Helen Keller International and Bangladesh's Nutritional Surveillance Project and Institute of Public Health Nutrition, the prevalence of iron deficiency is much higher, at nearly 70% for preschool-age children (Helen Keller Institute, 2006). Further research is needed to address this question.

Figure 1: Prevalence of zinc, iodine, vitamin A, and iron deficiencies for key risk groups (percent)



Source: icddr,b et al., 2013.

Recent findings from the *National Micronutrient Status Survey* (2011–2012) in Bangladesh show that zinc deficiency is especially problematic. Zinc is essential for health because it is involved in more body functions than any other mineral and is necessary for growth and development and maintenance of body tissues and the immune system. In addition, zinc deficiency causes stunting in children (WHO and FAO, 2002). Nationwide, 55% of people in Bangladesh (a greater percentage of the population than in any other Asian country) are at risk of zinc deficiency (International Zinc Nutrition Consultative Group [IZiNCG], 2014). It affects 45% of preschool-age children and 57% of NPNL women, some of the highest percentages in the world (icddr,b et al., 2013).

A nutrition problem of the scale and nature of zinc deficiency in Bangladesh requires a multifaceted and coordinated approach, as well as a substantial resource commitment. Unfortunately, with the exception of a few initiatives (e.g. HarvestPlus's biofortification program, Micronutrient Initiative's zinc oral rehydration salts [ORS] supplementation campaign, and icddr,b's Baby Zinc project), large-scale nutrition programs in Bangladesh have focused largely on fighting other micronutrient deficiencies. This has only amplified the need for comprehensive programming to combat zinc deficiency in Bangladesh.

Micronutrient deficiency in Bangladesh is to a large extent driven by a high dependence on a monotonous diet of low-cost, nutritionally inadequate rice. Rice constitutes 70% of the caloric intake in Bangladesh. The average Bangladeshi adult consumes more than 400 grams of rice on a daily basis (HarvestPlus, 2009) — the fourth-highest per capita consumption of rice worldwide (CGIAR, 1997). Given the rapid population growth and the low speed at which diets are changing in Bangladesh, consumption of rice is expected to continue to grow. While milled rice is rich in calories, it is low in micronutrients.

Given rice's role as a staple food, a rice-based intervention may be best placed to deliver micronutrients to large swathes of the Bangladeshi population. Compared to other approaches to addressing malnutrition, micronutrient fortification of a staple food such as rice at either the farming or processing stage is attractive because it can fit into existing consumption patterns, thereby limiting the extent or intensity of consumer behaviour change, while taking advantage of existing supply and distribution channels.

This paper, which is a compressed version of a longer, more-detailed report, aims to (1) identify how the rice value chain in Bangladesh can be used as the structure of a nutrition intervention and (2) explore the technical and market feasibility of potential nutrition concepts.

2. INTERVENTION POINTS IN THE VALUE CHAIN FOR ADDRESSING MICRONUTRIENT MALNUTRITION

While there are no panaceas to overcome the challenges of micronutrient deficiency, the rice value chain in Bangladesh presents multiple opportunities for enhancing the nutritional value of rice. Using a value chain approach (see Figure 2), there are two major areas where nutrition interventions can be focused because of the nature of the initiative and the dynamics of the sector: (1) farm inputs, such as seeds and fertilisers, and (2) post-harvest, through nutrient-sensitive milling and polishing practices. Opportunities in each of these areas are explored below.

Figure 2: Overview of the rice value chain in Bangladesh

Farm Inputs → Production and harvesting → Parboiling and milling → Trade and retail

2.1 Farm Inputs

Both seeds and fertiliser offer ready and relevant intervention points for on-farm nutrition interventions. Labour and irrigation are other key inputs to rice production but are not effective entry points for agriculture-nutrition initiatives. Pesticides are another key input, and while nutrient-enriched pesticides represent an emerging opportunity, the technology remains in its very early stages; therefore, it is not considered here.

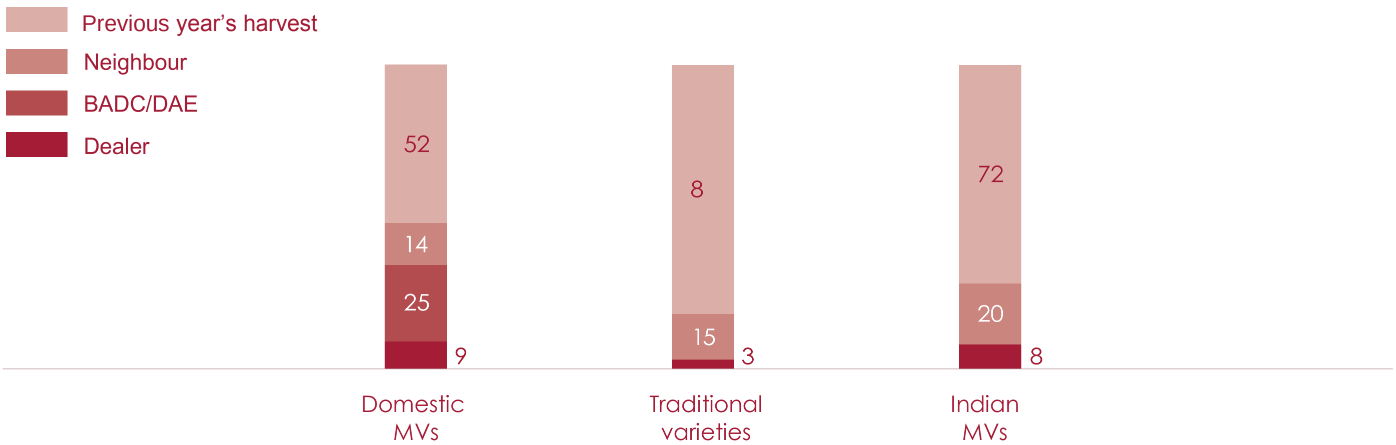
Seed Markets

Within the seed market, the primary intervention point for improving nutrition is through breeding nutritious rice seeds via biofortification. Biofortification is the process of making seeds more nutritious by breeding varieties with increased levels of micronutrients, such as vitamin A, iron, and zinc. This process is already under way — as of 2016, three high zinc rice varieties have been released.

Fifty percent of the current demand for quality rice seeds remains unmet by any source. This presents a market opportunity for higher-quality seed that is also more nutritious. Total annual demand for rice seed in Bangladesh increased by 15% to 30% between 2007 and 2011 (from roughly 300,000 tonnes in 2007–2008 to 350,000–400,000 tonnes presently), a phenomenon primarily driven by farmers' desire for high-yielding varieties (Jaim and Akter, 2012). However, the supply of quality seed was only about 180,000 tonnes in 2011–2012. This gap is primarily due to limited investment on the part of both the public and the private sector in improving the capabilities of breeding and quality control in the seed production industry (Parvez, 2011).

Farmers' lack of knowledge on how to maintain seed quality presents both a challenge and an opportunity for a nutritious seed product. Farmers' previous harvests are the most important source of seed across both traditional and modern varieties. Many farmers who recycle seed from year to year lack seed management skills and thus produce low-quality crops. If these farmers purchase and recycle nutritious rice seeds, the quality of nutritional content is not expected to change, but the overall productivity is expected to decline, particularly if the improved seed is mixed together with the non-improved seed stock. While sourcing from one's own stock remains a popular option for a majority of Bangladeshi farmers (Figure 3), an increasing number are beginning to abandon the practice of recycling seed in favour of purchasing better-quality seeds in the market, which is a promising trend for any seed-sector intervention, and nutrient-rich seed in particular (Parvez, 2011).

Figure 3: Source of rice seed by seed type, 2009 (percent)



Source: Jaim and Akter, 2012.
Note: BADC–Bangladesh Agriculture Development Corporation; DAE–Department of Agricultural Extension (Ministry of Agriculture); MVs–Modern varieties.

Engaging public sector agencies and non-governmental organisations (NGOs) already involved in rice seed development and distribution will be crucial for ensuring the efficacy of the intervention and widespread dissemination. The public sector is the most important source of modern domestic varieties in Bangladesh. Scientists from the Bangladesh Rice Research Institute (BRRI) are responsible for developing the majority of modern varieties in the country. The Bangladesh Agriculture Development Corporation (BADC) and contract farming partners are charged with multiplying the seed, and the Department of Agricultural Extension manages a large part of the distribution.

Overall, there is a clear opportunity for a seed-based nutrition intervention to succeed in Bangladesh. Farmers are increasingly demanding high-quality seed from the market, and public sector networks for disseminating seeds to farmers already exist and have indicated a willingness to distribute nutritious rice seed as long as agricultural traits are also up to par. Previous introductions of new varietals in Bangladesh suggest that efforts to bring high-quality seed to market could gain traction in the next 5–10 years. However, several risks must be managed for a seed-based intervention to succeed, including a potential lack of in-country breeding capacity and poor quality control of seeds in the market, which leads to market spoilage.

Fertiliser markets

Micronutrient fertilisers represent a second, but longer-term opportunity to integrate nutrition into farming practices. Micronutrient fertilisers are used primarily to improve plant quality by delivering more micronutrients to the crop, either through the soil or via a foliar spray. Research has shown that in addition to improving crop health, additional zinc can be loaded into the rice grain, thereby adding zinc to the diet when that grain is consumed.

Only 30%–40% of Bangladeshi rice farmers currently use zinc fertiliser, in contrast to the more than 90% who use conventional fertilisers, such as urea, muriate of potash (MoP), diammonium phosphate (DAP), or triple super-phosphate (TSP) (Kafiluddin, 2008). It is estimated that 50,000 tonnes of zinc fertiliser are required annually to meet the needs of Bangladesh's arable land, but only half of that amount is typically procured,[1] thus providing a market opportunity for zinc fertiliser products. The latest figures from the Soil Resource Development Institute (SRDI) indicate that about half of Bangladesh's arable land has some level of zinc deficiency. In addition

[1] Source: Interviews with fertiliser companies.

to existing zinc-deficient land, even soil that currently has enough zinc is at risk of depletion because of intensive rice production. A nutrition intervention focused on filling this gap in supply of zinc fertiliser would allow Bangladesh to successfully treat its zinc-deficient land while also improving human nutritional outcomes.

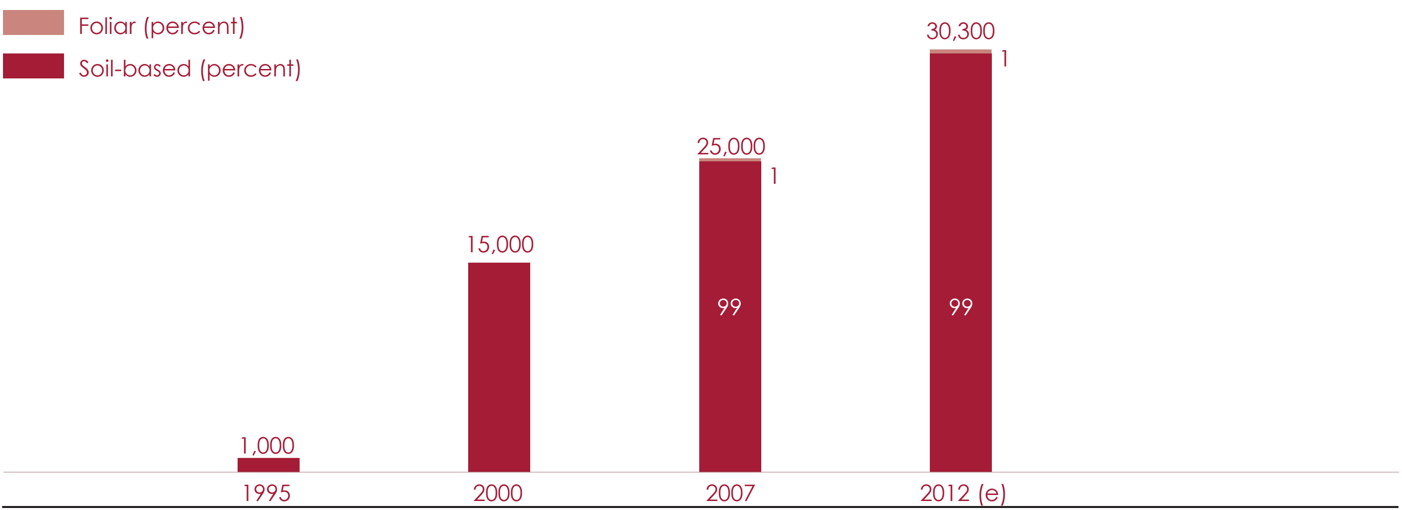
Zinc fertiliser is typically applied only in conjunction with a conventional fertiliser, which provides elements (e.g. nitrogen) that are essential to improving yields. Zinc fertilisers are usually applied in addition to, rather than in place of, these conventional fertilisers and therefore constitute an extra outlay for farmers. Consequently, zinc fertiliser is often underused, even by farmers who are planting on zinc-deficient soils. In addition to being an extra cost to farmers, the general lack of awareness of what zinc fertiliser is and why it is needed contributes to low uptake. Nevertheless, zinc fertiliser usage rates are climbing steadily, indicating that a fertiliser-based nutrition intervention could eventually have significant reach.

There are two primary types of zinc fertiliser used in Bangladesh — soil-based and foliar. Soil-based application is the dominant method and accounts for over 99% of all zinc fertiliser used in the country. Despite challenges related to affordability and awareness, the amount of soil-based zinc fertiliser used has doubled from 2000 to 2012, indicating that it is growing in popularity (Figure 4) (Barkat et al., 2010). Building awareness of why zinc fertiliser is useful, in addition to making it more affordable, could facilitate even greater demand for a fertiliser-based nutrition intervention.

Soil-based fertilisers are already widely used across Bangladesh and are substantially less expensive than foliar spray; consequently, a foliar-based intervention will face significant difficulties in farmer uptake. Only 1% of farmers in Bangladesh currently use foliar fertilisers, most likely because of the culture of soil-based fertiliser use and the prohibitively high price of foliar spray. Despite the fact that foliar zinc fertiliser is very effective at improving plant quality and health since it optimises zinc delivery to the plant, it is unlikely to succeed unless a nutritious rice intervention accounts for the significant behaviour change and price adjustments that would need to occur to encourage uptake.[2]

Fertiliser subsidies in Bangladesh do not currently extend to zinc fertilisers, which are already quite expensive compared to other products on the market. The per-kilogram (per kg) market price of soil-based zinc fertilisers (either soil- or foliar-based) is 6–10 times more than that of conventional fertilisers. Foliar is even more expensive and can be 3–4 times the price of soil-based fertiliser on a per-kg basis. Additionally, substantial subsidies of up to 25% are extended to TSP, DAP, and MoP, while no such subsidies exist for micronutrient fertilisers (Kafiluddin, 2008).

Figure 4: Estimated use of soil and foliar zinc fertiliser (metric tonnes)



Sources: A. Kafiluddin, 2008; Abul Barkat et al., 2010; interviews with SRDI and IFDC; Dalberg analysis.

[2] Source: Interviews with fertiliser companies.

Widespread contamination and adulteration of existing zinc fertilisers are a concern and have already led to substantial market spoilage. Zinc fertiliser tested in labs in Bangladesh shows evidence of heavy-metal contamination: 70% showed evidence of dangerously high levels of cadmium, 39% were above the maximum permitted amount for lead, and 10% were above the maximum amount for nickel.

Overall, implementing an intervention in this stage of the value chain is attractive given the 'double impact' of fertilisers, but several market barriers must be addressed to achieve success here. Foliar-based fertilisers can raise the nutrition content of rice while also having a positive effect on agricultural traits like yield and plant quality. These factors, in addition to expanding the reach of improved nutrition into farm households, are major advantages of implementing an intervention in this stage of the value chain. However, farmer affordability, quality control, and regulatory barriers are nontrivial risks that must be managed when attempting to execute a nutrition intervention in the fertiliser market.

2.2 Parboiling and Milling

Interventions in the milling sector present a key opportunity for nutritious rice because it is at this stage that most of the naturally occurring nutrients in rice are lost: On average, nearly 50% of the zinc and iron in common Bangladeshi rice varieties of brown rice is lost after the bran and husk are polished off (GAIN, 2013a). By developing an understanding of the incentives in the milling sector, and of the impact that different types of milling have on nutrition, there is a significant opportunity to develop a rice product that both is profitable to the miller and has positive nutritional impact for the consumer. There are two main processes that are part of the millers' domain, parboiling and milling, and three interventions that can take place in this stage of the value chain to improve the nutritional content of rice:

- nutrition-sensitive parboiling, which could increase the zinc and iron content in cooked milled rice
- reduced milling, which produces a moderate increase in the zinc retained in the rice grain
- fortificant soaking, which can significantly increase the zinc content of milled rice

There are several ways of milling paddy into rice, but in Bangladesh overall they follow the same four steps: (i) soaking and parboiling, (ii) drying, (iii) precleaning and de-husking, and (iv) polishing. Larger and more technically advanced mills have a fifth additional step of grading and packaging. These steps are described in Figure 5.

Figure 5: Overview of the milling process

Soaking and parboiling →	Drying →	Precleaning and de-husking →	Polishing →	Grading and packaging
• Raw rice paddy is soaked and subsequently steamed in large tanks.	• Rice paddy is then dried in the sun or mechanically (or a combination of both).	• The husk is removed from the rice grain through a mechanical process. • Husk is separated from brown rice and burned as fuel or sold as a by-product.	• The brown rice is stripped of the bran through a mechanical process. • Bran is separated from polished rice and sold.	• In technically advanced milling processes, a grading machine separates broken rice from head rice to produce high-quality polished rice. • A pre-selected amount of head and broken rice is blended into each bag of sellable rice.

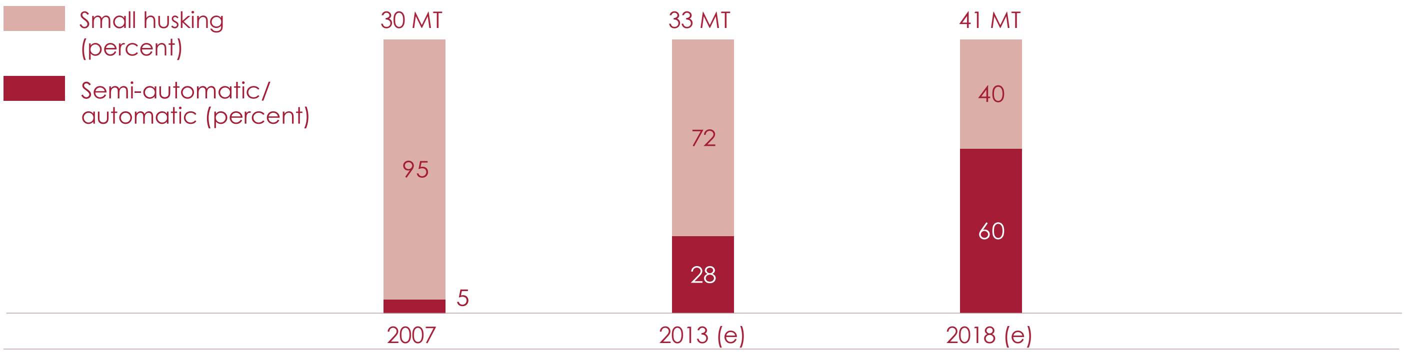
Sources: *GAIN,* 2013a; consultations with Christine Hotz (Nutridemics); Dalberg analysis.

The nutrition content of the final raw, milled rice grain largely depends on how it has been milled. The most popular milling methods used in Bangladesh are described below:

- *Traditional milling methods:* These include hand pounding using a *gail* (mortar and pestle) and low-tech devices such as the *dheki* and *dalan*, which are more sophisticated versions of the *gail*. Traditional milling is time- and labour-intensive (often performed by women in the household), compared to more modern methods of milling paddy, but yields more nutritious rice. Traditional methods of milling have production capacities ranging from 5 kg per day (*gail*) to 400 kg per day (*dalan*).
- *Small husking mills:* Small husking mills use Engelberg hullers, which are steel friction devices that use very high pressure to remove the rice husk after soaking. While popular in rural areas, small mills produce a large proportion of broken rice and very low white rice recovery (50%–55%). Small mills do not have polishing machines, so the nutritious quality of their rice is higher than that of semi-automatic and automatic mills. These mills have an average production capacity of 1,000 kg per day (Asaduzzaman et al., 2013).
- *Semi-automatic mills:* Semi-automatic mills are those in which all milling processes except paddy drying (soaking, parboiling, de-husking, and polishing) are mechanised; paddy drying remains manual. These mills use a colour sorter and a polisher, which lead to the production of whiter, more-polished, less-nutritious rice. The production capacities of semi-automatic mills vary widely, but on average these mills produce between 16,000 and 20,000 kg per day (GAIN, 2013b).
- *Automatic mills:* These are fully mechanised mills that also include automatic dryers used for drying paddy, allowing them to operate in the rainy season. While this has positive implications for food security in terms of providing enough quantities of milled rice, the fact that automatic mills tend to over-mill and polish rice means that the nutritious quality of the rice is lower. Similar to semi-automatic mills, the production capacities of automatic mills vary, but on average these mills produce between 41,000 and 48,000 kg per day (GAIN, 2013b).

The use of semi-automatic and automatic mills has been on the rise for several years now. In 2007, they handled only 5% of commercially milled rice; in 2013, they handled 25%–30% of the milled rice in Bangladesh, with the remainder of commercially milled rice coming out of small husking mills. This trend is expected to intensify over the next five years as semi-automatic and automatic mills continue earning market share because of the increased productivity advantage they have over small husking mills, as well as their ability to produce white, polished rice, which matches the preferences of most Bangladeshi consumers. By 2018, it is estimated that semi-automatic and automatic mills will handle almost 60% of all milled rice in the country (Figure 6).[3]

Figure 6: Share of annual milled rice production by mill type (in millions of tonnes)



	2007	2013 (e)	2018 (e)
# of semi and auto *(% of mills)*	**306** *(2%)*	**2,018** *(10%)*	**N.A.**

Note: Only mills that have a government license are included in this estimate. (e) Signifies estimated figures.
Source: Interview with Ministry of Food, Government of Bangladesh; Dalberg analysis.

[3] Source: Interview with Ministry of Food, Government of Bangladesh.

While a nutritious rice intervention focused on semi-automatic and automatic mills would primarily reach urban consumers in the short term, it would be accessible to rural consumers only in the long term. Most rice coming out of these mills goes to urban wholesalers; in fact, 90% of millers surveyed sold exclusively to this group. In addition, virtually all mills indicated that they believed that urban dwellers were the primary end-consumers of their rice — semi-automatic and automatic mills account for only 5%–10% of the rice that is consumed in rural areas (GAIN, 2013b). However, as the market share of semi-automatic and automatic mills continues to grow, rural populations will eventually have the opportunity to source and purchase this rice.

Given that margins tend to be low in the milling sector, many mills may be hesitant to risk participating in a nutritious rice intervention without guaranteed demand. Rice milling is a low-margin business, with profit margins at 0.8–1.0 Bangladeshi taka (Tk) per kg[4] on average across semi-automatic and automatic mills (GAIN, 2013b). Because per-kg margins are so low, millers depend on selling high volumes to make profits. As a result, they may be risk-averse when it comes to investing in a nutritious rice intervention that does not yet show evidence of having clear demand, despite the benefits that such a product could bring (e.g. the opportunity to showcase themselves as a socially responsible business and the chance to differentiate themselves in a very homogeneous market).

Modifying milling practices is not without risk. The lack of consistent oversight and quality control in the country could pose a problem for ensuring the quality of the nutritious rice produced. No one government ministry has control over regulating operations at rice mills. In terms of quality control, although the Bangladesh Standards and Testing Institute (BSTI) developed a set of quality standards for milled rice in 1981, these guidelines are voluntary rather than mandatory. As a result, most mills do not adhere to them. While there are a limited number of mills that do follow guidelines in order to receive a BSTI seal on their product, counterfeit seals are commonplace, making it difficult for consumers to know which rice is truly up to standards.[5] Experts indicate that consumers also do not place much value on the BSTI seal in the first place. It follows that mills could potentially sell normal rice at a premium while claiming that it is value-added nutritious rice, without any penalties.

Despite the risks, millers have shown initial interest in participating in a nutritious rice intervention. Although the majority of millers surveyed had not heard of miller-focused nutritious rice concepts before, once the nutritional benefits of the concepts were explained to them, over two-thirds of those surveyed indicated that they believed there would be demand for some type of nutritious rice. Moreover, over 60% of millers expressed willingness to invest in building demand for nutritious rice if convinced of a viable market (GAIN, 2013b). Virtually all mills indicated that they would require assistance in the form of external advertising and publicity generation, training, and technical or financial support to start producing and selling nutritious rice, underscoring the importance of providing some level of support to supply-side actors in the initial stages of a nutritious rice intervention.

Overall, the milling sector is a prime location along the rice value chain for a nutrition intervention like nutrition-sensitive parboiling, reduced milling, or fortifying the rice during the soaking process, considering the increasing mechanisation and consolidation taking place in the sector. As automatic mills with high production capacity grow in number and continue capturing market share, a nutritious rice intervention will have to engage with a smaller number of actors to achieve significant reach and impact — a characteristic that is largely unique to this stage of the value chain. Key risks to manage include the lack of quality control in the milled rice market and millers' potential hesitancy to take on a new product in a competitive market without guaranteed demand. These risks may be tempered by engaging wholesalers and retailers to participate.

[4] 1 USD = 78 Tk.

[5] Source: Interview with International Rice Research Institute.

3. UNDERSTANDING CONSUMER PREFERENCES, AWARENESS, AND WILLINGNESS TO PAY

A consumer survey, with a sample size of 1,250, was conducted to gain a better understanding of Bangladeshi rice consumers across four dimensions: sourcing, cooking, and eating practices; consumer preferences for rice; awareness of how preparation practices affect the nutritious value of rice; and willingness to pay for nutritious rice. Survey respondents were from six divisions of Bangladesh and spanned both rural and urban areas, as well as different socioeconomic groups.

3.1 Consumer Practices on Sourcing, Cooking, and Eating Rice

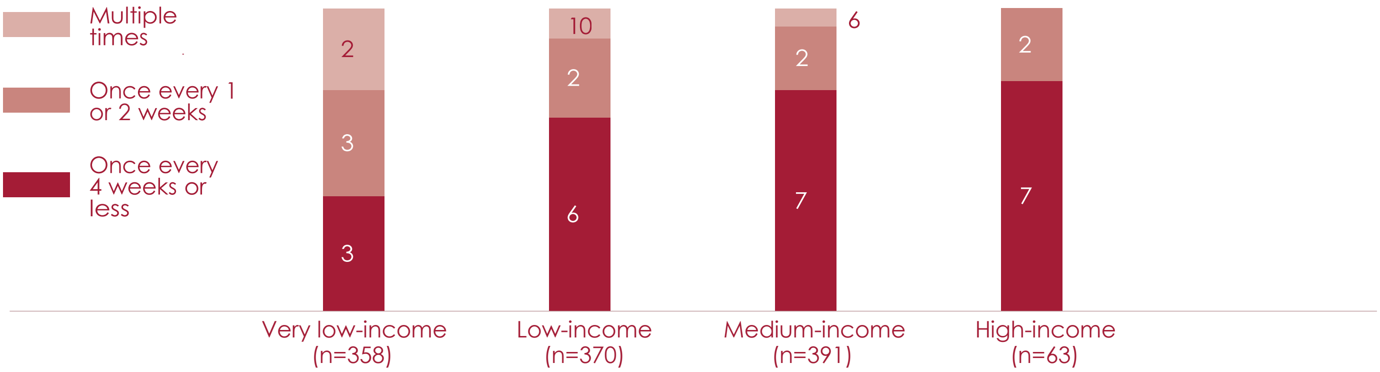
Sourcing Practices

According to the survey, 95% of consumers source their milled rice from the traditional retail market, in particular from rice-only market stalls and roadside kiosks, indicating the importance of these players in reaching consumers. Over 80% of all consumers who purchase rice buy some amount of their required consumption from rice-only market stalls, making them the most popular type of retail outlet in the country. Rice-only market stalls are frequented by rural and urban consumers alike and are equally popular across all socioeconomic groups. Roadside kiosks are also popular and are frequented by 24% of rice purchasers, likely because of their convenient location, the wide variety of products that they stock, and their ability to sell rice to consumers in variable quantities. Despite the inherent fragmentation in their distribution, they will be important players to engage with on any nutritious rice product. Wholesale markets can also be a point of sale for consumers; however, only 13% of buyers cited them as their primary market of choice. These markets are more attractive to consumers who have a steady income stream, can afford to make bulk purchases of rice (50 kg or more), and have sufficient storage space in their home.

Farmers tend to source the majority of their rice from their own production, implying that on-farm nutrition strategies will have significant reach in rural farming households. Survey results indicate that 80% of farmers fulfil at least half of their household’s rice consumption requirement from their own farm. In particular, larger farms can rely more on their own production for their rice than smaller ones: Farms that are smaller than 1 hectare source roughly half of their required consumption from the farm, while farms larger than 1 hectare source up to 85% of their consumption from their own production (Bangladesh Bureau of Statistics, 2011). Even among smaller farms that tend to sell paddy as a way to procure cash for other household needs, fewer than 5% of farmers surveyed end up selling all of their rice without consuming any of it. Consequently, nutritious rice interventions at the production level, such as zinc fertilisers, will likely be more effective in reaching farmers in rural areas, who consume large portions of their intake from the farm, than will interventions implemented later in the value chain.

Purchasing habits and patterns change dramatically on the basis of socioeconomic status, and this has significant implications on the marketing, packaging, and branding of nutritious rice. According to the survey, on the whole, low-income consumers tend to purchase mostly loose rice on a more frequent basis and in smaller quantities. They tend to buy rice at least once a week, if not more frequently, and 20% of them buy in quantities of less than 5 kg per purchase. Additionally, three-quarters of low-income consumers purchase all of their rice in loose form because this type of rice tends to be cheaper and easier to afford in small quantities. Higher-income consumers, on the other hand, tend to purchase larger quantities of packaged, branded rice on a more infrequent basis. Roughly 75% of medium- and high-income consumers purchase rice once a month or even less frequently. Over 80% of them buy in quantities of 20 kg or larger, which is consistent with how often they are going to the market. Finally, over 40% of these consumers buy exclusively packaged, branded rice. For nutritious rice interventions aiming to reach low-income consumers, selling in loose form to facilitate the purchase of small quantities will be necessary. On the other hand, if the rice is to be positioned as an aspirational product through sales to high-income consumers first, a strong brand and use of bulk packaging will be more appropriate.

Figure 7: Frequency of rice purchases, by income group (percent)



Note: There were 68 non-responses, which are not included here. Source: *GAIN Bangladesh Consumer Survey,* 2013.

Figure 8: Average quantity of rice purchases, by income group (percent)

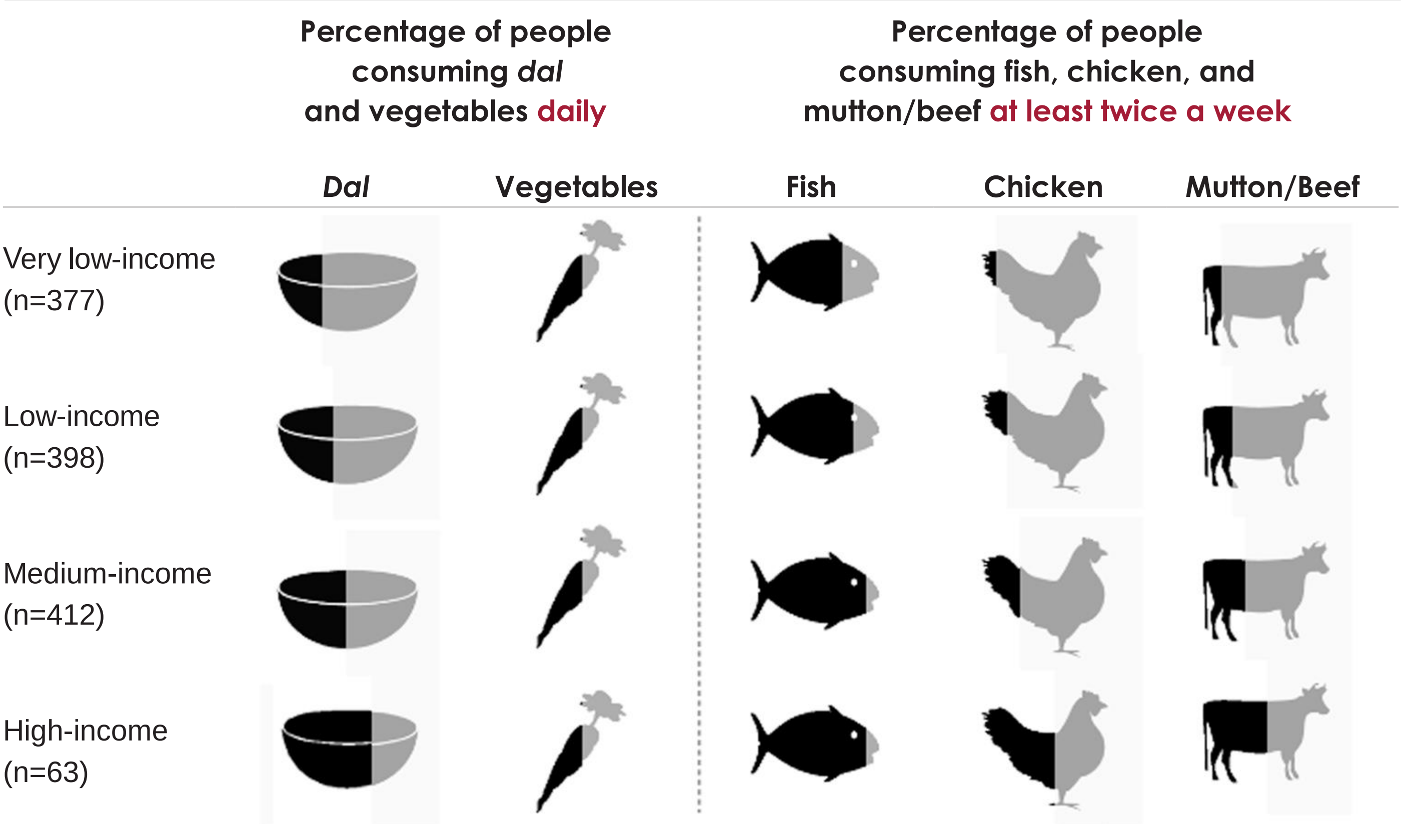
Note: There were 68 non-responses, which are not included here. Source: *GAIN Bangladesh Consumer Survey,* 2013.

Eating and Cooking Practices

While rice is widely consumed across the country, the consumer survey found that rural and lower-income individuals eat it the most frequently, indicating that a nutritious rice intervention could have the most impact on these groups. The majority of consumers (98%) eat rice at least twice a day regardless of location or income level, confirming its status as the main staple food of Bangladesh. However, while 73% of rural consumers eat rice three times a day (for breakfast, lunch, and dinner), only 30% of urban consumers do the same. This is the case because urban dwellers have the advantage of being in close proximity to a greater variety of food options. In the same vein, while roughly half of individuals falling into the three lowest income brackets consume rice three times a day, only 11% of high-income individuals do the same. This is largely because high-income individuals can afford to purchase other foods.

Along with rice, three-quarters of consumers in the survey reported eating vegetables on a daily basis; however, particularly among low-income populations, consistent consumption of *dal* and access to animal protein remain limited, underscoring that these groups likely experience higher rates of malnutrition. Roughly 70%–75% of all consumers eat vegetables on a daily basis, regardless of income levels. However, *dal* consumption is more limited for low-income populations. While nearly 60% of high-income consumers eat *dal* every day, fewer than 40% of very low- and low-income consumers do so. Consumption of fish is also popular across income groups, although there is wide variance in its consumption. Only 75% of very low-income consumers eat fish twice a week or more, as compared to 90% of medium- and high-income consumers. However, richer consumers are much more likely than others to consume rice with chicken, mutton, or beef: Fewer than 10% of very low- and low-income consumers indicated that they ate mutton, beef, or chicken with rice at least twice a week, compared to over 40% of high-income consumers.

Figure 9: Percentage of consumers eating various foods with rice, by income group



Note: Shading is representative of the percentage of people in that income bracket who are consuming the specified food at the indicated frequency.
Source: *GAIN Bangladesh Consumer Survey,* 2013.

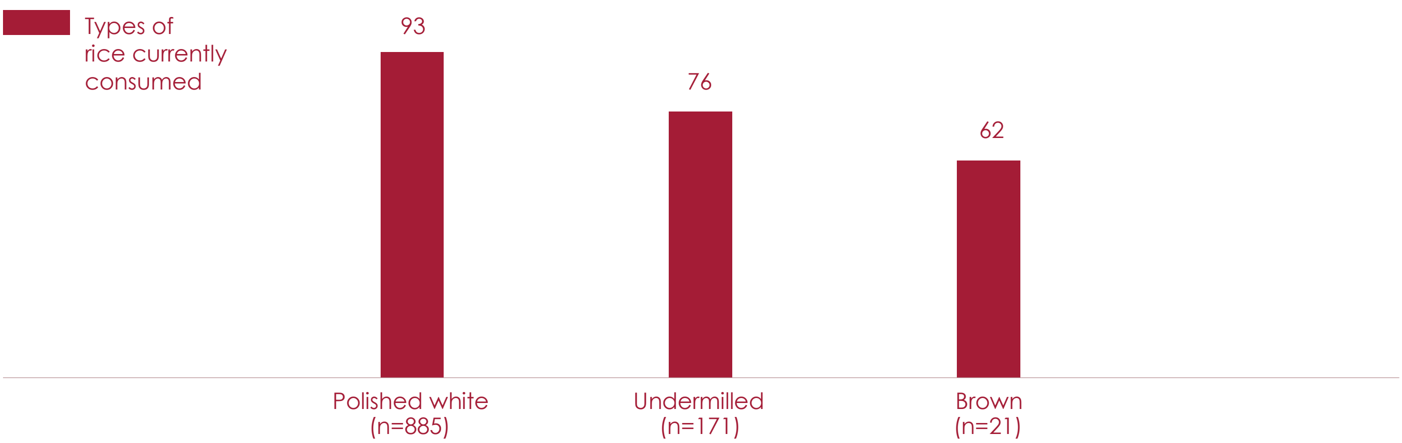
Cooking practices and preferences relating to the amount of time that rice stays edible after cooking are generally consistent across the country, according to the survey. In general, consumers across rural and urban areas cook rice twice a day. Additionally, roughly half of consumers across regions prefer a keeping time of 4–6 hours; this is also true within the three lowest income brackets.

However, it is worth noting that very low-income urban consumers tend to cook less often and, as a result, require a longer keeping time (8+ hours) than other groups; a nutritious rice product focused on this segment would need to take this preference into account. The survey found that nearly 25% of very low-income urban consumers noted that they cook rice only once a day, a higher proportion than among their counterparts in rural areas and in higher-income groups by almost 10 percentage points. In addition, over half of these consumers preferred a keeping time of 8+ hours, as compared to 40% across other consumer subsets. Based on targeted interviews with consumers in Dhaka, this behaviour and preference is driven by employment in garment factories. Garment factory workers — who generally fall into the very low-income bracket — have time to cook rice only once a day in the morning due to their long working hours (typically up to 12 hours a day, 6 days a week). Since they can cook only once, interviewees indicated that these consumers want rice to keep for longer than other consumers might. Nutritious rice interventions that reduce the shelf life of cooked rice will not be suitable for targeting this particular segment.

Consumer Preferences for Rice

Bangladeshi consumers overwhelmingly prefer fine-grained, white rice, and developing an affordable and accessible nutritious rice product that matches this preference would help attract consumer adoption. Overall, the consumer survey found that 80% of all consumers prefer to eat milled, polished white rice, while 88% prefer fine-grained rice. These preferences largely hold true across regions and income levels, although richer consumers tend to prefer fine-grained rice in greater proportions than low-income ones. There is a strong preference for white rice even among those who reported eating other types of rice — over three-quarters of consumers eating less polished rice and nearly two-thirds of those eating brown rice would prefer to be eating whiter, more polished rice. However, it is likely that their consumption is limited because their location is not serviced by a semi-automatic or automatic mill that produces these varieties or because the varieties are too expensive. If a nutritious rice product were able to fulfil these aspirational preferences, could be offered at an affordable price, and could be made accessible through the appropriate points of retail, there could be significant adoption across a variety of consumer segments.

Figure 10: Consumers' preference for types of rice (percent)



Source: *GAIN Bangladesh Consumer Survey,* 2013.

In addition to preferring white, well-milled rice, the survey revealed that consumers have a host of other preferences that will be important to consider in order for a nutritious rice product to achieve uptake. When assessing raw rice, consumers across regions and income levels consistently place the most value on smell, cleanliness, grain size, translucency, and colour. In terms of preferences for cooked rice, consumers ranked taste, cleanliness, smell, nutrition, and keeping time as the most important characteristics to consider.

The fact that consumers value nutrition relatively highly as a quality of cooked rice is a positive finding for the prospect of a nutritious rice intervention. Based on the preferences mentioned above, a nutritious rice product will be most attractive to a broad swath of consumers if the raw product is fine-grained, clean and white, and has an acceptable smell; the cooked product must be tasty, have a relatively long keeping time, be clean, and have an acceptable smell, similar to its raw grain. Finally, given that many consumers have difficulty in articulating how to define an acceptable taste and smell for both raw and cooked rice, these two dimensions will need to be tested and validated through focus group discussions and consumer taste tests.

One noteworthy point is that a nutritious rice product must also take into account regional variations in preferences for non-parboiled rice in the Chittagong and Sylhet divisions, where 63% of consumers surveyed preferred to eat non-parboiled rice and were already doing so. While the survey did not target consumers living in Sylhet, interviews with several rice experts in Bangladesh corroborate that consumers in this division also prefer non-parboiled rice. In the rest of the country, parboiled rice is preferred by over 90% of consumers. A nutritious rice intervention that aims to roll out a product on a countrywide basis should take this regional variation into account.

3.2 Consumers' Knowledge of Milling Effects on Nutrition

While most consumers are aware of the fact that milling decreases nutritional quality, a majority of them would still prefer milled rice because of other qualities. Nearly 60% of consumers surveyed were aware that milling and polishing decreases the nutritious value of rice. However, 74% of these consumers still consume white, polished rice and 80% of them would prefer to consume more of it. These results underscore the fact that Bangladeshi consumers value other qualities of rice over nutrition content, which, as mentioned in the previous section, should be considered when developing a successful nutritious rice intervention. Additionally, nutritious rice that matches consumer preferences for white, well-milled rice could potentially be positioned as an 'aspirational' product for poorer consumers and achieve uptake in that way.

Consumers are less knowledgeable about the effects of washing and cooking; only about 30% of those surveyed understand that these household processes decrease the nutritious value of rice,[6] while almost two-thirds believe that washing and cooking have no effect on the nutritional content of rice. Even among consumers who understand the negative effects of washing, almost 80% still wash their rice three or more times. The benefits that consumers perceive from over-washing (e.g. cleanliness) outweigh the benefits that they attribute to the nutrients that could be retained by washing the rice only once or twice. Over-washing is likely to continue unless concerted efforts in both awareness-building (ensuring that consumers understand the effect of over-washing on nutrition) and behaviour change (creating new washing habits among consumers) take place.

Awareness levels as to how milling, polishing, washing, and cooking affect the nutritious value of rice are more or less similar among rural and urban consumers. Additionally, higher educational levels are not correlated with a better understanding of nutrition; in fact, 62% of illiterate people surveyed knew that milling and polishing decreased the nutrition content of rice, a greater proportion than that of people with high school-level diplomas or higher who were aware of the fact (57%).

3.3 Consumers' Willingness to Pay

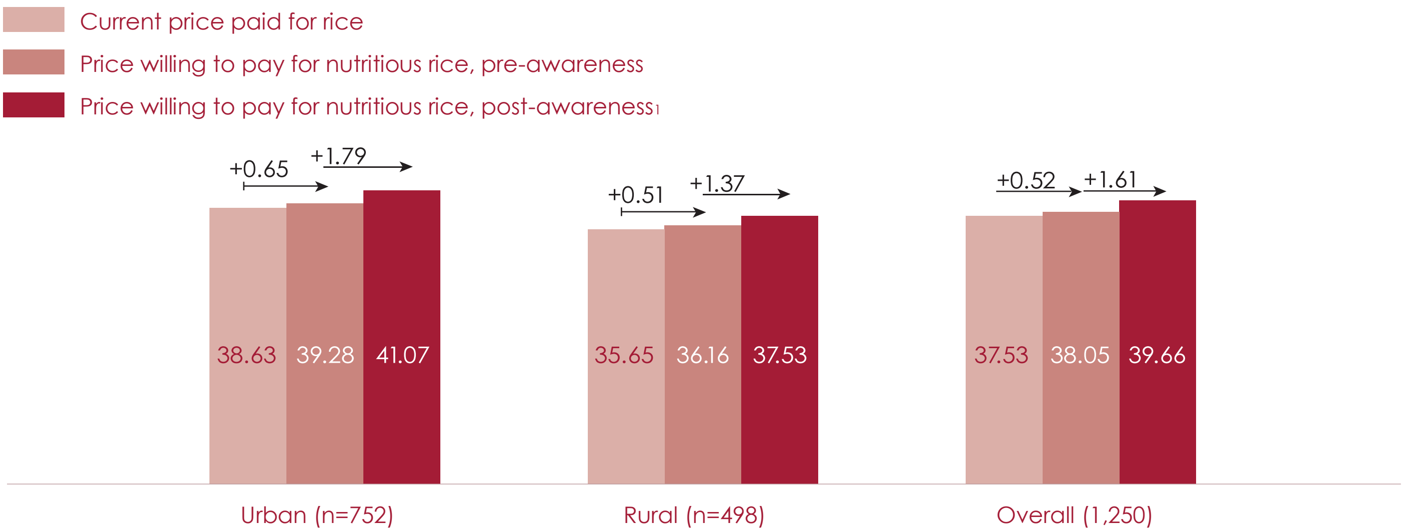
Consumers across urban and rural locations are equally likely to pay a premium for nutritious rice, and the

[6] It is common practice in Bangladesh to rinse rice in water multiple times prior to cooking and to cook rice in excess water and pour off unabsorbed water. These practices lead to increased losses of nutrients from the rice.

likelihood of paying a premium increases with income. Roughly 85% of consumers in the survey indicated that they would pay more for healthier rice that retains normal physical characteristics in terms of taste, aroma, and appearance. These consumers are spread proportionately across rural and urban areas. However, the likelihood of a consumer paying a premium for nutritious rice depends largely on income: While roughly 90% of medium- and high-income consumers indicated that they would pay more for healthier rice, only 75% of very low-income consumers said that they would want to do so. As expected, low-income consumers are more sensitive to price changes than richer consumers and would be less likely to pay a premium for nutritious rice despite the fact that they would likely stand to benefit the most from such a product. A nutritious rice intervention targeting low-income consumers should take into account their lower willingness to pay a premium for nutritious rice and should plan for incentives such as consumer discounts and consider coupling other incentives with nutrition, such as cooking time and keeping time.

Extensive messaging on the benefits of nutritious rice, namely the benefits for children, will increase the average price consumers are willing to pay for healthier rice by 1.6 Tk per kg. Before receiving awareness education,[7] consumers indicate that they are willing to pay only about 0.5 Tk more on average for healthier rice with the same organoleptic properties as regular rice. After receiving awareness education, both rural and urban consumers are willing to pay substantially more for nutritious rice. Overall, awareness education is successful at increasing the price urban consumers are willing to pay for nutritious rice by 1.79 Tk per kg, while it raises the price rural consumers are willing to pay by 1.37 Tk per kg, as shown in Figure 11. A successful nutrition intervention will likely require some component of awareness-building and consumer education in both urban and rural areas to encourage consumers to pay the necessary premiums for nutritious rice.

Figure 11: Willingness to pay a premium for nutritious rice before and after awareness messaging, by location



Consumers were provided brief awareness education via the survey question: 'If you were told that this rice (a) provided you and your family with vitamins, (b) would help prevent diarrhoea/other diseases for your family, particularly children, and (c) made the children stronger, what would be the fair price for this rice?'
Sources: *GAIN Bangladesh Consumer Survey*, 2013; Dalberg analysis.

[7] Awareness education was contained in the question posed to consumers during the survey: 'If you were told that this rice (a) provided you and your family with vitamins, (b) would help prevent diarrhoea/other diseases for your family, particularly children, and (c) made the children stronger, what would be the fair price for this rice?'

Fortunately, most households already have access to technology that can be used to disseminate and receive messages on nutrition and nutritious rice. Virtually all households surveyed have a mobile phone in the household. According to the survey, television ownership is also widespread, with 87% of urban households and 62% of rural households owning a colour TV. Moreover, almost all households surveyed indicated that they have access to electricity, although it is unclear from the survey how reliable the supply is. These existing avenues for communication could potentially allow consumers to receive messaging on nutrition via educational text or voice messages and/or televised public service announcements or advertisements.

4. IDENTIFYING AND PRIORITISING POTENTIAL NUTRITIOUS RICE INTERVENTIONS

This section provides an overview of four specific nutrition interventions that can be embedded in the rice value chain:

1. Fortificant soaking: the process of adding a micronutrient[8] during the soaking process at a mill
2. Reduced milling: reducing the degree to which the rice is milled ('degree of milling' [DoM]) from 10% to 4%–6%)[9] to maintain more of the nutritious bran on the rice grain that is consumed
3. Zinc fertiliser: the addition of zinc-enriched fertiliser, either at the root of the plant (soil-based) or sprayed on the leaves (foliar) to increase zinc content in the grain at the farm level
4. Nutrition-sensitive parboiling: modifying the temperature and/or soaking time during parboiling to improve micronutrient retention in the rice grain

4.1 Approach

This feasibility analysis takes into account the baseline situation and context in Bangladesh, as well as the progress made on specific concepts to date, to provide an accurate snapshot of the feasibility of each of these concepts. GAIN identified a series of questions that would lead to a better understanding of the market potential and technical feasibility of each of these concepts. These questions are outlined below.

- **Increase in zinc content[10]:** What is the estimated increase in zinc content in milled, washed, and cooked rice as a result of the intervention?
- **Evidence of demand:** What is the extent to which there will be 'natural' demand for the product based on its organoleptic qualities and price changes (if applicable)?
- **Supply chain capacity:** What is the ability and capacity of the existing supply chain for rice to integrate the changes required to produce the nutritious rice?
- **Regulatory environment:** How conducive are government policies and the enabling environment to the concept?
- **Initial support required:** What level of upfront investment is needed to make this idea a reality?
- **Time to market:** Inclusive of research, development, and dissemination, how long will it be before the concept can be scaled in a market environment?
- **Ultimate reach:** Based on the target demand groups and overall trends in the rice value chain, what is the potential reach of the concept?

4.2 Overall Findings

While there are some concepts that show more potential than others, there is strong merit in considering some of these concepts as a portfolio of options to be pursued simultaneously or in a layered approach. There are significant differences across these concepts in terms of target population and overall reach, investment horizon and timeline, and progress to date. For example, fortificant soaking is a concept still in the ideation stage and would likely target the urban population first. However, the most attractive target demand group for fertilisers in the short run is on-farm rural consumers. Given the scale of the problem in Bangladesh, pursuing each of these concepts in coordination makes it more likely that micronutrient deficiencies will be addressed across a wide set of population groups.

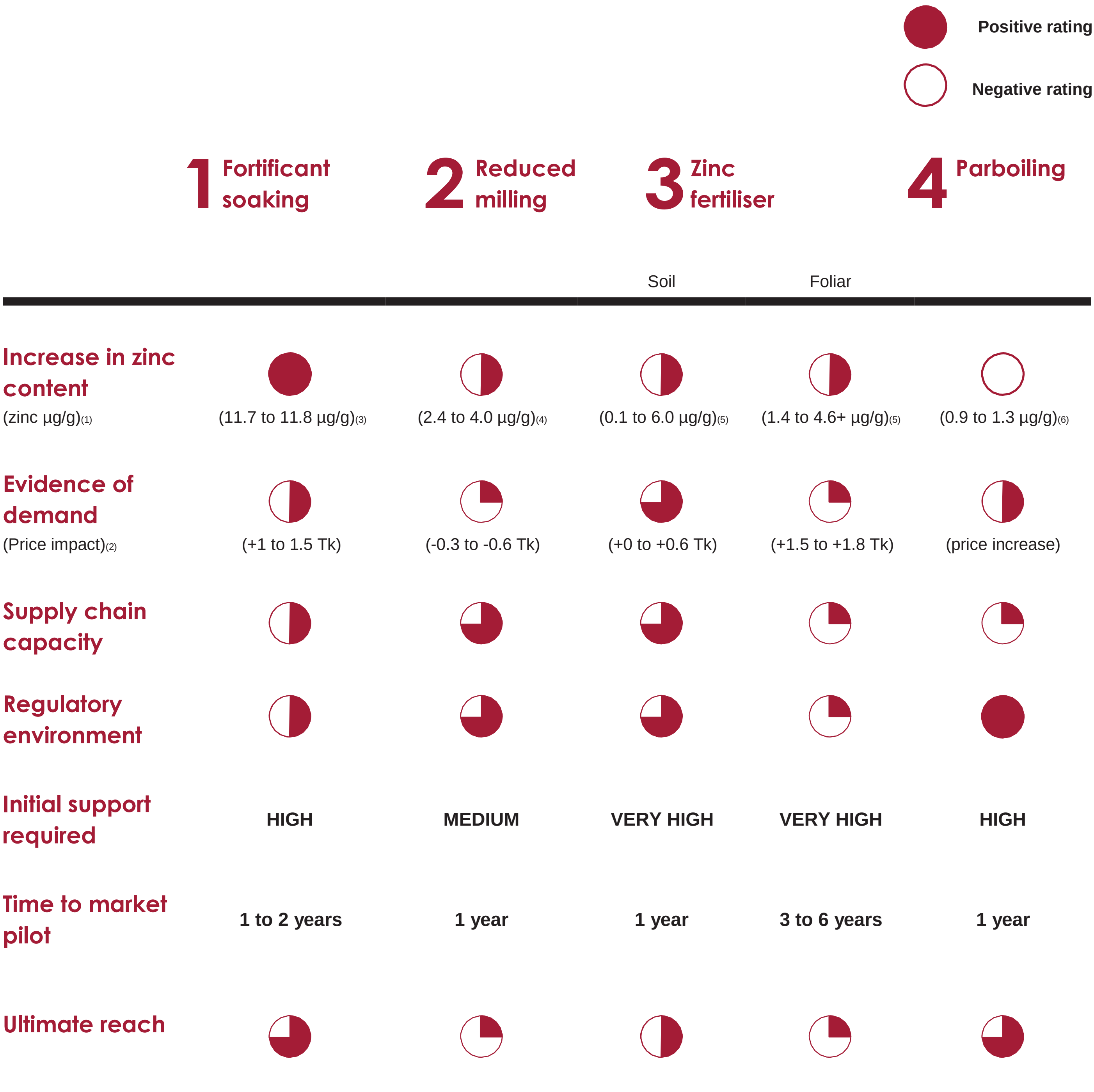
From this assessment, fortificant soaking emerges as a strong concept to pursue in the Bangladeshi context. It demonstrates the potential for strong nutritional impact and the ability to put a significant dent in the prevalence of zinc deficiency in Bangladesh, despite serious challenges, including generating demand and negotiating the regulatory environment. Fortificant soaking is likely easier to implement from a supply chain perspective as it does not require millers to make large upfront investments.

A comparative assessment of these concepts in the context of each of the questions noted above is included in Figure 12.

[8] This report focuses primarily on adding zinc to the mill processing, although other water-soluble micronutrients could be added at this stage.
[9] DoM is expressed as the weight of outer fractions of brown rice grain removed by milling as a percent of the weight of brown rice.

[10] As further research and data become available on many of these concepts, this metric should be amended to be 'amount of zinc available after consumption' in order to more effectively compare overall impact as it applies to humans.

Figure 12: Comparative market and technical feasibility assessment across nutritious rice interventions



(1) Increase in zinc content of milled, washed, and cooked rice.
(2) Demand assessment relies on multiple factors; impact on price is not the only dimension used for rating.
(3) This is for a 1,100 mg $ZnSO_4$ solution treatment.
(4) This is ranked lower because increased phytate levels in reduced milled rice decrease the ultimate nutritional impact of the concept.
(5) Fertiliser values are based on literature review; for soil-based fertiliser, +0.1 µg/g of zinc is in zinc-adequate soils, and +6.0 µg/g is in zinc-deficient soils; for foliar fertiliser, the range is given for zinc-adequate soils only; data do not exist for impact on zinc-deficient soils, but foliar fertiliser impact is likely to be higher than soil-based fertiliser.
(6) This figure is not statistically significant and the rating is therefore lower.

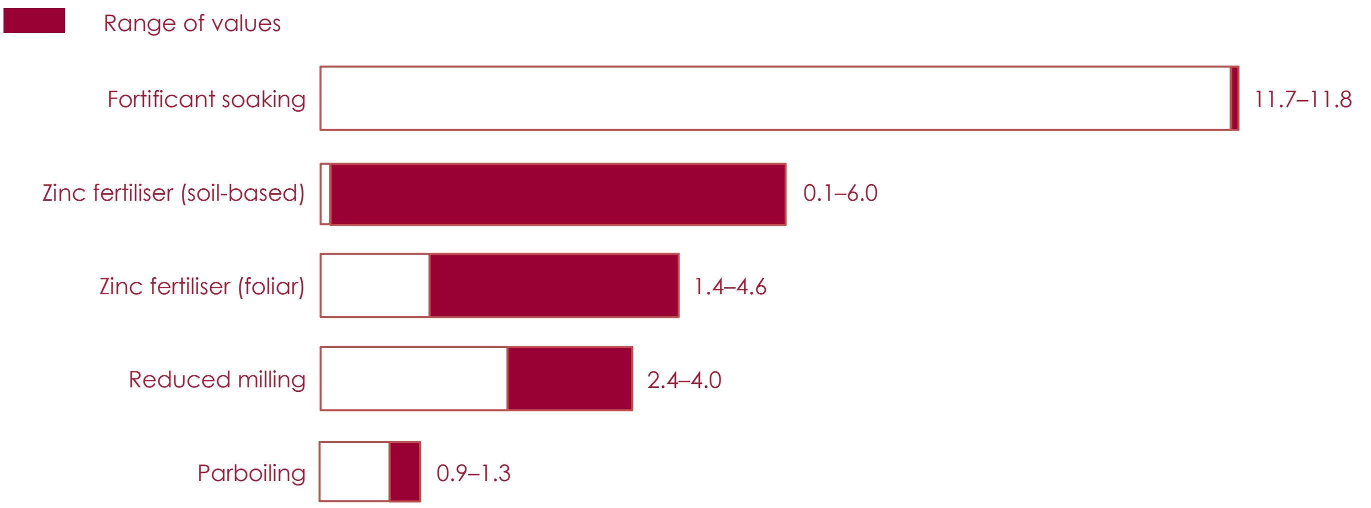
Sources: *Gain Bangladesh Nutritious Rice Technical Assessment,* 2013; interview with World Food Programme; Dalberg analysis.

4.3 Summary of Key Findings

Increase in Zinc Content

One criterion is paramount: A concept should not pass for further analysis if it cannot show that it can significantly improve zinc content in rice grain. In collaboration with BRRI and researchers from Waite Analytical Services in Adelaide, Australia, GAIN conducted a series of nutrition absorption and retention studies. Figure 13 outlines the estimated increase in rice grain zinc content as a result of the interventions assessed in this report based on laboratory tests and secondary literature review.

Figure 13: Estimated increase in rice grain zinc content in cooked milled rice (µg per gram of rice)



Sources: *GAIN,* 2013a; Dalberg analysis.

Across all four concepts, the intervention with the most promise for improving zinc content is fortificant soaking. Lab results using 1,100 mg of zinc sulphate per kg paddy resulted in an increase of 11.8 µg per gram of zinc in the cooked milled rice; this could have a significant impact on nutritional outcomes. Reduced milling, soil-based fertiliser, and foliar fertiliser also show promise but face their own distinct challenges. While reduced milling does demonstrate increased zinc content, the process also increases phytate content, which can have a negative impact on bioavailability (i.e. the extent to which the human body absorbs zinc). Soil-based fertiliser can create significant impact on zinc content in rice when applied in zinc-deficient soils. In zinc-adequate soils, however, soil-based fertilisers have limited impact on zinc content. Foliar fertiliser can improve zinc content, even in zinc-adequate soils and is expected to have an even greater impact in zinc-deficient soils. However, there is insufficient research to date to support this latter hypothesis. Further research may make this a more attractive option from an impact perspective.

Nutrition-sensitive parboiling is the one concept that did not demonstrate significant increases or improvements in the zinc content of rice in GAIN laboratory trials. As a result of these findings, this concept was not pursued for further analysis.

Evidence of Demand

Integrating nutritious rice into existing consumer preferences and habits, to the extent possible, is a clear advantage for any intervention, as it requires less behaviour change and improves overall adoption rates. Fortificant soaking and parboiling do not drastically change the overall appearance, smell, or colour of milled and cooked rice. Further consumer testing is required to test the taste and organoleptic properties of fortificant-soaked rice under industrial pilots. These concepts will, however, increase the final retail price of rice. Fortificant soaking, for example, will likely increase the price by 1.0–1.5 Tk per kg, which is within the premium that consumers have said they are willing to pay. Nonetheless, educating consumers on the value of zinc-soaked rice will require substantial investment.

Reduced milling and foliar fertiliser will face an uphill battle in terms of consumer acceptability. Because significantly reducing polishing time may change the final taste, appearance, storability, and smell of the rice, it will be harder to convince consumers to purchase it, even if it is slightly cheaper than standard rice. With regard to foliar fertiliser, farmers do not typically use it (only 1% of the zinc fertiliser used in the country is foliar), the product does not improve plant yields, and it is an expensive outlay for farmers. In addition, without a subsidy, it will result in a price increase of between 1.5 and 1.8 Tk per kg, which is in the upper range of the premium that consumers are willing to pay for nutritious rice. Much like soil-based fertiliser, the product is unlikely to result in any changes to the appearance, smell, and cooking qualities of the rice.

Supply Chain Capacity

All of these interventions will require changing the supply chain in some way to integrate the nutritious element into the final rice product. However, concepts that require more-limited change in the existing supply chain will be in a better position to achieve success.

Of the concepts under consideration, reduced milling implies the least amount of change in the supply chain. Millers will not have to purchase any additional equipment; they will only have to change slightly the configuration of their existing equipment to produce the reduced 4%–6% milled rice. Doing this will require some initial technical training, but it will be minimal. In fact, reducing milling time has built-in incentives, as it reduces energy costs for millers.

For soil-based fertiliser, there is an existing supply chain that can be used, but it is weak and poorly monitored. For the concept to be effective, a more robust and extensive supply chain will have to be developed.

The fortificant-soaking concept will require the creation of a supply chain for zinc premix to add to the soaking water in measurable quantities. Initial research suggests that this is time-consuming, but there is existing capacity at the local and global levels. It will also require some process changes at the miller level, although these are within millers' capacities to execute given that many of them are already adding ingredients to the soaking water to enhance the 'whiteness' of rice. The primary challenge will likely be in recruiting millers to produce the rice and take on the additional cost, with assurance of sufficient consumer demand.

Foliar fertiliser and parboiling will require more significant changes. For foliar fertiliser, the supply chain will have to be developed almost from scratch. For parboiling, changes in water temperature, particularly heating it to a higher temperature, would significantly increase energy costs and constitute a substantial change to the process.

Regulatory Environment

There is wide variation in the regulatory environment as it pertains to rice production, processing, and sale in Bangladesh. Understanding where each of these concepts fits into the existing environment is important, as it will facilitate or delay the implementation of the intervention.

Parboiling is likely to face the fewest challenges within the regulatory environment, as there is no mandatory guidance on rice processing and milling, and this rice would still be eligible for government procurement channels. Reduced milling and soil-based fertiliser may have to overcome some regulatory hurdles of a different sort. Given that reduced milling will reduce the overall shelf life of the product, it is not likely to be eligible for government procurement. If a soil-zinc fertiliser formulation that is already available on the market is used, then there will be no regulatory issues. However, if a new product is developed, it will take a substantial amount of effort and time to ensure that the product is approved for distribution.

Fortificant soaking will face regulatory challenges centred on managing the taxes and import duties on micronutrient premix powder and quality control for fortified rice in the market place. Since there is already experience in importing and using zinc sulphate in the pharmaceutical industry, regulatory issues for premix importation are likely to be manageable, although it is as yet uncertain whether fortificant-soaked rice will be eligible for government procurement. The Bangladesh government, in partnership with others, would need to play a prominent role in developing a comprehensive quality control framework for zinc-fortified rice to ensure that low-quality products cannot infiltrate the market, spoiling it for the high-quality nutritious rice product.

Foliar fertiliser is the concept that will face the greatest number of regulatory challenges. Because of its low use in Bangladesh and the fact that the product in use (10% chelated zinc) does not have a very high zinc concentration, it is very likely that a new product will have to be formulated. This will require a multiyear regulatory approval process through multiple agencies, which will delay implementation of the concept.

Initial Support Required

For all of the concepts, some initial level of support will be needed to establish and scale them up. This support can range from conducting upfront research, developing a viable product, and providing initial technical capacity building for the producers to running an awareness campaign and setting up a discount fund to spur initial consumer adoption.

Reduced milling will likely require the least support because the primary changes will occur at only one stage of the value chain and there is limited technical training that will be required. There will be investments in generating awareness and some policy support, but in relation to the other concepts, it will be minimal.

All the other concepts will require similarly high levels of initial support from external actors to create the market for the product along the lines outlined above. Zinc fertiliser (both foliar and soil-based) will require higher levels of support than other concepts because of the investment required to develop the initial product, as well as significantly higher investments in awareness and capacity building across thousands of small, fragmented farms.

Time to Market Pilot

Because of the complexity of the process and the initial support required to define and develop it, each of these concepts will require a different length of time to reach the market.

Reduced milling, soil-based fertiliser, and parboiling are expected to take the least time to market as the processes are not technically complex, nor do they require significant amounts of upfront research. As such, they can be rolled out to a market pilot in about a year.

Fortificant soaking would likely take slightly longer given that the production process is more technically complex and requires some upfront research and investment to develop and tailor it to the Bangladeshi context. As such, a market pilot may take up to 2 years to roll out.

Foliar fertiliser would take the longest because significant work would be required for product development and for ensuring regulatory approval before the product could be released to consumers. These processes will likely take 3–7 years from product research initiation to market pilot.

Ultimate Reach

Fortificant soaking and parboiling are expected to be able to reach the broadest number of people over the course of 5 years, if the stated challenges could be addressed. This concept is thus tentatively supported for three main reasons:

- These interventions can accommodate all rice sent through the milling system.
- They are targeted at semi-automatic and automatic millers, which are growing and are expected to control over 60% of the market in the next 5 years. While in the short run, the consumer segment reached will be the urban population, where potential benefits and consumer acceptability are likely to be high, they could expand to include rural populations as markets continue to consolidate.
- These processes have marginal impacts on the organoleptic properties of the rice, and the price premium falls into the range that consumers said that they are willing to pay for nutritious rice.

The remaining concepts are expected to have a more limited reach for a variety of reasons. Reduced milling will be limited because of the associated changes in organoleptic qualities that may not make it palatable to all consumers. For zinc fertiliser, which targets the farmer, its reach beyond farmers is limited in the short term to on-farm rural consumers. As an integral supply chain from farm to fork would have to be set up for the zinc-fertilised rice to avoid being diluted with non-fortified lines at the mill, it would be difficult to reach a broad set of consumers off the farm. For zinc fertiliser, its reach is somewhat limited because only farmers who are on zinc-deficient soils are likely to use it, and foliar fertiliser is particularly limited because of its high cost.

5. POTENTIAL NUTRITIOUS RICE INTERVENTIONS IN DETAIL

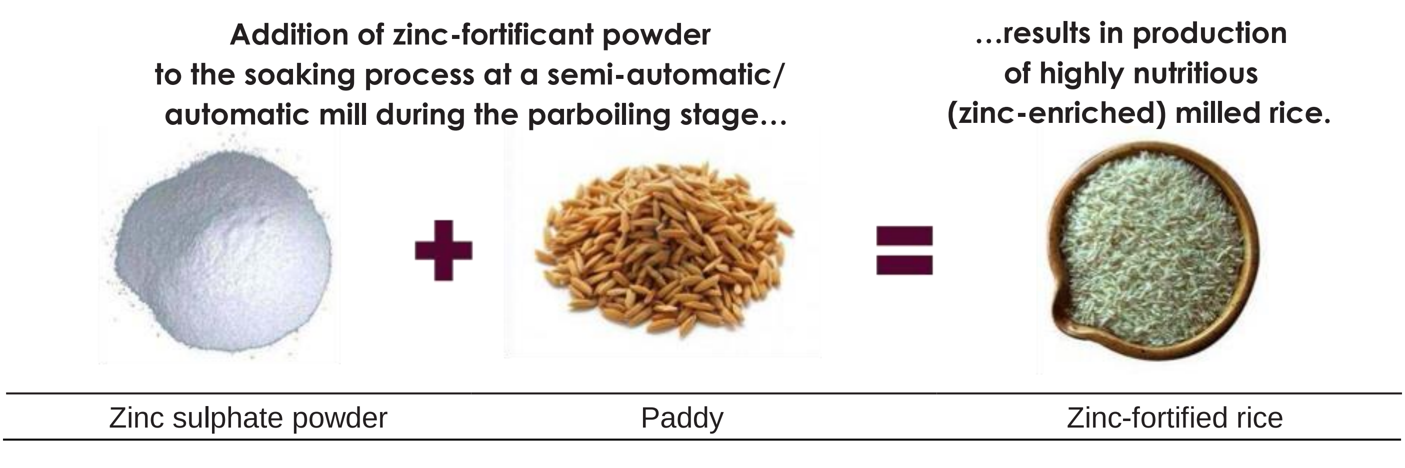
This section provides an elaboration of the four potential interventions discussed in the previous section. Parboiling is given a more cursory analysis because it was not deemed to have significant nutrition potential, and therefore was not prioritised for further detailed analysis. Other potential nutritious rice value chain strategies have been under development, namely zinc biofortified rice varieties and fortified milled rice using multi-nutrient fortified extruded false rice grains as a premix. Given the efforts by others to evaluate the potential for these strategies, they were not considered for detailed analysis here. However, a summary of their potential for comparison purposes is included in **Annex 1**.

5.1 Fortificant Soaking

Fortificant soaking is the process of adding a micronutrient powder to rice paddy in the soaking process (Figure 14). In this case, the focus is on zinc sulphate, and initial recommendations suggest that up to 1,000–1,100 mg of the water-soluble, food-grade zinc sulphate powder would need to be added to the soaking water per kilogram of paddy. Once the paddy is milled and processed into rice, it will retain more zinc and be a healthier food option for consumers.

There are several reasons why fortificant soaking has emerged as the most promising concept among those studied. First, fortificant soaking with zinc is likely to create substantial nutritional impact. It results in one of the highest increases in zinc content of the rice grain, and therefore the level of zinc delivered/absorbed by the human body is also likely to be high. While the method still requires adaptation and testing in large-scale facilities, initial laboratory-scale results indicate that the zinc content of rice grain increased by as much as 17 µg per gram dry weight of milled cooked rice when very high amounts of zinc sulphate were applied (Hotz et al., 2014).[11] A nutrition modelling exercise suggests that, if broadly adopted, fortificant-soaked rice could improve mean zinc intake to reach 6.38 mg/day (from a baseline of 4.82 mg/day) for NPNL women, assuming that 70% of women adopt it. In addition, it could decrease the population of women with zinc inadequacy by 55 percentage points and by 17 percentage points for children (Hotz et al., 2014). This impact is expected to be scaled up significantly given the higher concentrations of zinc used.

Figure 14: What is zinc-soaked rice?



[11] Fortificant soaking with zinc is expected to have the largest nutritional impact among all the concepts that were evaluated. Laboratory studies used up to 1,300 mg zinc in soaking water per kg paddy. However, considering costs, results from the 1,100 mg zinc per kg paddy tests were assumed for this concept (Figure 13).

Second, there is strong evidence of demand for nutritious rice in Bangladesh. Initial surveys suggest consumers are willing to pay for more nutritious rice that has the same organoleptic properties (taste, smell, texture, and appearance) as the rice they usually eat, which fortificant-soaked rice does. Rice millers also indicated that there would be demand for nutritious rice and that consumers may be willing to pay a premium if it is marketed effectively. Third, there appears to be a fit for fortificant soaking within the rice supply chain in Bangladesh. Several changes and adaptations would be necessary, in particular changes to the milling process, but these are expected to be within the capacity of the semi-automatic and automatic mills that will anchor this concept.

There are also several important challenges to the successful implementation of the concept. First, rice millers with semi-automatic and automatic mill operations would need to be convinced to take on the additional cost of fortifying rice through soaking. To fortify the rice, millers would need to procure the right quality of zinc sulphate fortificant premix, invest in dosing and metering equipment, and invest in training workers, processes that would add between 1.0 and 1.5 Tk per kg of rice. Given the very small operating margins of millers, they are likely to pass this cost on to consumers. In initial surveys, millers did express a willingness to invest in and produce nutritious rice, provided that there was proof of market demand.

Second, consumers require education on the value of zinc-soaked rice and persuasion to purchase rice at a higher price than what they currently pay. Again, there is evidence from the consumer surveys to support that this could be achieved, but it will require targeted investments in awareness and marketing. The support of the enabling environment, including government, NGOs, and donors, would be required to overcome these challenges.

Third, there is a risk of market spoilage with regard to poor-quality zinc-fortified rice (i.e. using lower-than-recommended dosage or adulterated premix could drive consumers away permanently). To mitigate this, the proposed Nutritious Rice Millers Association would need to implement a quality and standards program, conducting regular tests in mills to ensure quality of both premix and zinc-soaked rice.

Finally, waste and excess zinc sulphate solution from the soaking tanks would result in environmental contamination if not treated or extracted in some way. Research would be required to develop a safe and cost-effective disposal process, which could add to the estimated production cost.

Low- and medium-income urban groups (approximately 4.9 million households) should be the primary short-term target for this concept because, in addition to the significant zinc deficiency in this segment, their rice is sourced from semi-automatic and automatic mills, which are best placed to produce this fortified rice, and consumer surveys indicate that this segment has the ability and willingness to absorb the expected 1.0–1.5 Tk per kg increase in price. As an increasing number of rural households consume rice produced at semi-automatic and automatic mills over time, the reach is expected to expand into rural segments.

Commercialisation should be anticipated within 5 years of starting a market pilot. If implemented, there would need to be two stages: a market pilot followed by a scale-up period. The initial year-long market pilot would seek to recruit five semi-automatic and automatic mills. During this phase, millers should receive financial assistance to help test this new processing method, essentially taking offline their conventional product while new fortified rice is processed on an industrial scale. Work should also build on current government support, and consideration should be given to starting an industry association, a training program, a quality control program, a research program, and a marketing campaign. The experience of these initial market-leading millers could be used to recruit more millers. The years following the market pilot would require the full rollout of the marketing and awareness campaign, the quality control and assurance program, and the technical training program for millers. With all these different elements, commercialisation could be expected to be achieved by the fifth year of the program.

5.2 Reduced Milling

Reduced milling is the process of reducing the DoM, which results in higher retention of nutrients in the rice grain. Under-milled rice is 4%–6% DoM, while polished white rice is 10%–12% DoM. In cooked milled rice, reducing the DoM from 10% to 6% boosts zinc content by an estimated 2.4 μg per gram. A 4% DoM boosts zinc content by 4.0 μg per gram. According to initial results, consumption of under-milled rice could increase adult zinc intake by 0.6 mg over a baseline average daily intake of 5.5 mg per day.

While reduced milling increases zinc retention in the rice grain, it also results in a higher phytate content, which will reduce the zinc available for absorption within the body. However, results from the nutrition-modelling exercise suggest that the effect will still be net-positive, although limited. Reduced milled rice would decrease the population with zinc-inadequate diets by only 6 percentage points among women and 9 points among children (Arsenault, 2013). Taken together, these results suggest that while reduced milling may not be viable or cost-effective as a stand-alone concept, it could prove to be an interesting complement to other concepts like fortificant soaking.

Figure 15: Description of reduced milling concept

Brown rice	Reduced milled rice	Polished, white rice
• 0% DoM • Paddy is de-husked • Full bran content is retained	• 4%–6% DoM • Some amount of bran is left on reduced milled rice • Typically reddish-brown hue	• 10%–12% DoM • Almost all of the nutrient-rich bran is removed • Rice is white in colour

Increasing degree of milling
Decreasing levels of nutrients in rice grain

Sources: *GAIN Bangladesh Nutritious Rice Technical Assessment,* 2013; Dalberg analysis.

Overall, while there are positive arguments for pursuing reduced milling as a nutritious rice intervention, there are also some critical challenges. On the positive side, reduced milling is likely to be popular with millers, who stand to increase profit margins by 1.0–1.5 Tk per kg as a result of energy cost savings and increased production volumes. The changes that would be required to the standard production process in a rice mill are not extensive or complicated and so should be easily within the millers' capacity to execute. The price of under-milled rice is likely to be the same as or less than that of standard polished rice, so consumer ability to pay is unaffected. There would be no regulatory obstacles, as the overall market for rice in Bangladesh is not regulated.

However, reduced milling has inherently less potential for nutritional impact compared to other methods. The boost in adult daily intake of zinc from consumption of under-milled rice would still fall significantly short of the minimum recommended amount for zinc. Second, consumers in Bangladesh have a longstanding and increasing preference for highly polished milled rice and are unlikely to appreciate the organoleptic changes (taste, aroma, appearance) of under-milled rice. Significant investment in marketing and awareness campaigns would be needed to change those consumer preferences. Third, the standardisation of production techniques would be challenging and would complicate the quality control process in automatic and semi-automatic mills.

5.3 Zinc Fertiliser

Zinc fertiliser-enriched rice is produced by growing rice paddy with zinc fertiliser (Figure 16). Based on the product and mode of application, this can improve the zinc content in the rice paddy, which translates into increased zinc content in the milled and cooked rice as well. In terms of nutritional impact, zinc fertilisers when used on zinc-deficient soils could increase the zinc content in cooked milled rice grain by up to 6.0 µg per gram, resulting in as much as a 54 percentage point reduction in inadequate zinc intake among women and a 17 percentage point reduction among children (Arsenault, 2013).

Figure 16: Description of zinc-fertilised rice

Addition of zinc fertiliser at the paddy production stage… **…results in production of nutritious (zinc-enriched) milled rice**

Zinc fertiliser	Rice paddy plant	Zinc-enriched rice

Soil fertiliser is by far the most widely used of the two fertiliser options in Bangladesh and comes either as a granule or as a dust that is applied directly to the soil. It is recommended that farmers apply 5–10 kg per hectare to have optimal impact on yield and plant quality improvements. The effects can last for a number of seasons without needing to be supplemented. Given that it can result in improved productivity of the rice crop, soil fertiliser is gaining in popularity among farmers and is currently used by 30%–40% of them.[12] Foliar-based fertiliser usually comes as a powder to be mixed with water or as a liquid that can be sprayed directly on the plant. Farmers are instructed to apply it to their crops in amounts of 1.5–3.0 kg per hectare, mixed with 150–200 litres of water, to achieve improvements in plant quality. Foliar fertiliser should be applied at least twice after the plant flowers and needs to be applied every season. Foliar fertiliser is significantly more expensive than soil-based fertiliser, its application is more complex, and it has minimal impact on plant yields although it can improve plant quality. As such, it is not currently popular in Bangladesh and is used by fewer than 1% of farmers.[13]

As noted above, there is moderate to severe zinc depletion in soils in Bangladesh, which presents an opportunity for fertilisers to improve yields and nutritional quality. According to the latest statistics from SRDI, about half of the arable land in the country has some degree of zinc deficiency. In addition, more than 60% of the land has not received any zinc fertiliser treatment in the last decade. These issues can and should be addressed with zinc fertilisers, which could have positive results not only for farmers' livelihoods but for overall nutritional outcomes as well.

While there is potential for both soil and foliar fertiliser, there are a number of challenges to scaling these concepts in the short term. There are several advantages to soil-based fertiliser. It increases plant yields by as much as 32%, which leads to higher farmer incomes, therefore providing a clear impetus to buy the product. In addition, there is an existing supply chain for the product, and farmers are aware of the product and how to use it. However, zinc soil fertilisers are effective only when used on zinc-deficient land, implying that it must be a highly targeted intervention, and even then,

[12] Source: Interviews with ACI Agribusiness and SRDI.

[13] Source: Interviews with zinc fertiliser experts.

there remains debate among experts as to how effective it can be. It would also be important to improve quality control of the fertilisers, as existing programs are limited: More than 85% of both domestic and imported products are adulterated and do not meet minimum quality levels.[14] Foliar fertiliser is more likely to improve nutritional impact across all soil types, and the number of farmers using it in Bangladesh is growing. However, foliar fertiliser does not have significant yield benefits, is expensive, and can likely be afforded only by medium-sized and large farms. There are also significant regulatory obstacles because foliar fertilisers are not well established. In addition, given the fact that all foliar fertiliser is imported, there would have to be significant partnership and investment with the private sector to scale up the supply chain for foliar fertiliser.

In addition to the two types of zinc fertiliser discussed here, there is another ‘zincated urea’ fertiliser product under development. This new type involves adding a zinc core inside a urea briquette and is being developed by the International Zinc Association (IZA) and the International Fertiliser Development Centre (IFDC). In the past, conventional zincated urea was produced by spraying zinc onto the urea. However, the spraying equipment was expensive, and the zinc coating was often lost during transportation. The new method overcomes these challenges through its novel zinc core technology. Since this technology is still in the early stages of development, it is not considered here but could be a promising alternative to consider if positive results emerge (Brouwer, 2011; Kuhn, 2012).[15]

5.4 Nutrition-Sensitive Parboiling

Nutrition-sensitive parboiling involves steaming rice at the milling stage and then drying the rice. Parboiling typically results in firmer, less sticky rice that takes less time to cook.

While previous studies of parboiling practices indicated the potential to increase micronutrients by adapting the process, laboratory tests in Bangladesh indicated this was not the case for zinc. Parboiling of rice paddy has been known to increase the thiamine content of milled rice, and limited research suggests that changing the soaking temperature and time in parboiling also increased the iron content of milled rice. However, the laboratory studies conducted by GAIN noted only modest increases in zinc content in cooked milled rice (+0.9 µg per gram) when pre-steaming soaking time was decreased from 48 to 24 hours in ambient water. For hot-water soaking as part of parboiling, soaking time was reduced from 9 to 3 hours and resulted in a 1.3 µg zinc per gram increase in cooked, milled rice. All of these results were statistically insignificant. Moreover, when compared to other interventions, particularly fortificant soaking, this change is limited and did not yield any practical recommendations for modifications. As such, a more cursory analysis was conducted for this concept.

[14] Source: Interviews with fertiliser companies.

[15] Source: Interview with IFDC Bangladesh.

6. CONCLUSIONS AND RECOMMENDATIONS FOR ACTION

There is a portfolio of options that can and should be considered as part of an agriculture-nutrition strategy in Bangladesh. While there is no 'one size fits all' solution, there are multiple options in the rice value chain that, individually or, more effectively, in combination, could enhance the nutritional value of rice. Given the issues regarding nutrition that the country is facing, especially for women and children, the time for planning and action is at hand.

6.1 Key Findings

Of the four concepts examined and presented here, fortificant soaking presents the most convincing way to embed nutrition in the agricultural rice value chain as it has a high potential to improve the nutritional density and therefore impact on human nutrition. Reduced milling could be considered an additive concept as it is not a technically complex idea, but it has limited nutritional impact. Zinc fertiliser offers an interesting opportunity to improve nutritional outcomes primarily in rural areas. Each concept has its merits and challenges, and, depending on the resources and timeline available, multiple concepts can be pursued in parallel. Most of these concepts have the potential to improve health and livelihoods for the significant proportion of the Bangladeshi population suffering from micronutrient malnutrition.

Some of the key insights are:

- The milling/processing sector is one of the most promising areas of the rice value chain for near-term nutrition interventions because it is here that most nutrients in rice are lost, and the sector is consolidating rapidly and increasing its reach and control of the milled rice market.
- Across all potential interventions, fortificant soaking and extrusion technology fortified rice (see the annex) have the most potential for nutritional impact. The impact of reduced milling is more limited. Zinc fertiliser, as well as biofortification (see the annex), could have significant impact, but these are longer-term interventions.
- A majority of consumers across income groups stated that they are willing to pay an average additional 1.0 to 1.6 Tk per kg for nutritious rice (a 2%–4% price increase) once they are aware of its health benefits.
- Although government regulation of the milled rice sector is limited, rice is a politically sensitive commodity, and private and public sector stakeholders emphasised that it is important to engage government early and often.
- All potential interventions will require some upfront investment to generate demand and interest for the product. This will be much harder for interventions that change the taste, smell, or cooking properties of the rice, such as reduced milling, as Bangladeshis have very specific and strong preferences for white, polished, and milled rice, a preference that is expected only to intensify in the future.
- With the exception of under-milled rice and soil-based zinc fertiliser, all concepts will result in a final rice product with a premium of between 0.4 and 2.0 Tk per kg, the majority of which is within the stated willingness to pay.

6.2 Recommendations

No matter the concept, finding ways to implement these ideas in the Bangladeshi context will not necessarily be easy. All of these interventions require some level of change from the status quo, and they all need to involve multiple partners, from private-sector millers to specific government agencies. Given the complexity of the task at hand for any agriculture-nutrition intervention, GAIN recommends using the following five principles to inform any strategy or decision making involved in defining, developing, or implementing an agriculture-nutrition intervention.

(1) **Use existing and emerging market forces and trends across the agricultural value chain in your favour.** While agricultural markets in developing countries may seem stagnant, there are often trends just below the surface that have implications for the success of any intervention. For example, consolidation of the supply chain at

the miller level is a key trend that can help support the successful implementation of a number of the concepts described in this paper. Moreover, Bangladeshi consumers have historically preferred white, polished rice, and that preference appears only to be intensifying over time. These types of trends can make or break an agriculture-nutrition intervention.

(2) **Lead with demand.** Do not underestimate how deep-rooted and entrenched consumer preferences can be, and plan accordingly. Food has strong and deep ties to culture, society, and family. Food preparation and consumption practices are developed over a long period of time and are often passed down across multiple generations. The consumer survey launched in Bangladesh clearly identified that consumers across all income groups had strong preferences when it comes to their rice products. Where possible, matching these preferences is advisable. If behaviour change is needed, it will require long-term and significant investments in generating consumer awareness and marketing.

(3) **Marketing should not be just about awareness, but about persuasion.** In many interventions, the assumption is that educating the consumer about 'bad' and 'good' behaviours will be enough to actually effect change. However, it is often more complex than that. For example, although the survey of rice consumers in Bangladesh revealed that consumers recognised that highly polished, over-milled rice was less nutritious, they continued to prefer and purchase the over-milled rice. To change behaviour, campaigns will need to go beyond simply delivering general awareness to directly influencing and incentivising purchasing behaviour by deploying more powerful and nuanced marketing components that are participatory and immediate to the consumer.

(4) **Engage key local market leaders and influencers within the nutritious rice production chain early in the concept design process.** Identifying and developing appropriate and effective concept champions would be crucial to categorically establishing proof of concept and then persuading other market players to also adopt and invest in the concept. For example, among millers in Bangladesh, the ideal target would be prominent players who combine market share with a commitment to quality and are seeking to be innovative.

(5) **Concentrate initially on generating broad-based political interest and establishing support for the nutritious rice concept from relevant government actors.** Regulation of staple food products in developing countries is complicated and politically sensitive. It is therefore critical to secure national support from government early on to ensure that there is buy-in to the approach. Government support and aid for a nascent nutritious rice concept, even in the absence of mandatory policies, would help convince important stakeholders including private-sector players to engage with the concept.

7. REFERENCES

Arsenault, J. (2013). 'Modeling the impact of Nutritious Rice Value Chain (NRVC) interventions on the adequacy of zinc intakes by women and children in Bangladesh', not published.

Asaduzzaman, M. et al. (2013). *Productivity and Efficiency of Rice Mills in Bangladesh: Economic, Social, and Food Security Implications*. Report prepared by the Bangladesh Institute for Development Studies (BIDS) for the International Food Policy Research Institute (IFPRI) under the Policy Research and Strategy Support Program.

Bangladesh Bureau of Statistics (2011). *Bangladesh Household Income and Expenditure Survey (HIES)*, 2011. Available from: <http://www.bbs.gov.bd/PageReportLists.aspx?PARENTKEY=66>.

Barkat, A. et al. (2010). *A Quantitative Analysis of Fertilizer Demand and Subsidy Policy in Bangladesh*. Dhaka, Bangladesh: Manob Sakti Unnayan Kendro.

Brouwer, G., ed. (2011). *Zinc in Fertilizers Newsletter*, Issue No.5. Available from: <http://www.zinc.org/crops/resourceserve/zinc_in_fertilizers_newsletter_august_2011>.

CGIAR (1997). 'Bangladesh: Rice Is Life'. CGIAR *Newsletter*, Volume 4, Number 3.

Embassy of the United States of America, Dhaka (2012). 'U.S.-Funded Study Shows True Cost of Malnutrition in Bangladesh'. Available from: http://photos.state.gov/libraries/bangladesh/8601/2012%20Press%20Releases/USAID%20malnutrition%20study_%20Jun%2025_%202012.pdf.

GAIN (2013a). *Nutritious Rice Value Chain in Bangladesh. Report on Technical Studies*, (unpublished).

GAIN (2013b). *Embedding Nutrition in the Rice Value Chain in Bangladesh: A Review and Assessment of Intervention Opportunities* (full report), unpublished.

HarvestPlus (2009). *Zinc Rice Strategy.* Washington, DC.

Helen Keller International (2006). *The Burden of Anemia in Rural Bangladesh: The Need for Urgent Action.* Nutritional Surveillance Project Bulletin No. 16. Dhaka, Bangladesh.

Hotz C. et al. (2015). 'Rice fortification with zinc during parboiling may improve the adequacy of zinc intakes in Bangladesh'. *Journal of the Science of Food and Agriculture*, 95: 379–385.

International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) et al. (2013). *National Micronutrient Survey (2011–2012)*. Dhaka, Bangladesh.

IZiNCG (2004). 'Assessment of the risk of zinc deficiency in populations and options for its control'. *Food and Nutrition Bulletin,* 25 (supplement 2): S91–S204.

Jaim, W.M.H. and Akter, S. (2012). *Seed, Fertilizer, and Innovation in Bangladesh: Industry and Policy Issues for the Future.* Project Paper. Washington, DC. IFPRI.

Kafiluddin, A. (2008). *Fertilizer Distribution, Subsidy, Marketing, Promotion and Agronomic Use Efficiency Scenario in Bangladesh.* Presented at 2008 IFA Crossroads Asia-Pacific, Melbourne, Australia, 16–18 December 2008.

Kuhn, T., ed. (2012). *Zinc in Fertilizers Newsletter,* Issue No. 7. Available from: <http://www.zinc.org/applications/resourceserve/zinc_in_fertilizers_newsletter_issue_ no._7>.

Parvez, S. (2011). 'Leaving It to Market Forces'. *The Daily Star.* 09 May 2011.

WHO (World Health Organisation) and FAO (Food and Agriculture Organization of the United Nations) (2002). *Human Vitamin and Mineral Requirements, Report of a Joint FAO/WHO Expert Consultation, Bangkok, Thailand.* Rome.

ANNEX

Biofortification

While not a focus of GAIN activities, rice biofortification is currently being developed in Bangladesh and has the potential for significant nutritional impact. HarvestPlus and its local partners are driving biofortification efforts with the development and dissemination of three waves of high-zinc and high-iron rice varieties. The target nutritional impact of biofortification is expected to be moderate to significant, with HarvestPlus and its partners aiming to increase zinc content of non-milled rice grain from 16 to 24 µg per gram (or the equivalent of 5 to 6 µg per gram in cooked milled rice) in the final varietal that is released.[16]

Biofortification has a number of advantages: It can reach rural consumers, it is not expected to face issues from a consumer acceptability perspective, and the regulatory environment is supportive. Biofortification, as an upstream intervention, is primarily targeted at rural farmer consumers and is intended to be scaled up only to urban retail markets as a discrete ‘nutritious rice’ product in the long run. HarvestPlus and BRRI are working to develop biofortified varieties that resemble currently popular modern varieties, to ease the process of replacement so that farmers would not have to drastically change existing practices. End-consumer acceptance of biofortified rice is expected to be similar to acceptance of normal rice varieties, as it is being bred to produce rice that will look, feel, and taste similar to existing popular modern varieties of rice. Finally, due to advocacy done to date, there is as supportive regulatory environment and a strong distribution system that can be leveraged.

However, significant upfront investment is required and the impacts would be felt only in the long run. The research and development stages of developing a new biofortified variety are costly. HarvestPlus, BRRI, and local partners have already borne the majority of this cost, but further large investments will still be needed to continue to develop better zinc-rich varietals (as initial varietals are precursors to the overall target set for increased zinc content). Once developed, seed multiplication and dissemination of biofortified varietals cost as much as any normal varietal. However, seed registration and approval, development of foundation seed, and multiplication of seed together comprise a 3- to 4-year process. In addition, uptake by farmers is not expected to grow beyond 5% in the first 5–10 years.[17] As such, even though the earliest varietals were released in 2013, it would take a decade to see significant impact.[18]

Extrusion Technology Fortified Rice

Extrusion technology, a process that involves the blending of rice flour with micronutrient premix and extrusion of the steamed mixture to form recomposed rice kernels, can be used to produce fortified rice. These recomposed kernels are mixed at a given ratio with natural rice to increase its nutrient content to a specified level. They are designed to look, feel, and cook like regular rice. Early evidence from a nutritious rice program administered by the World Food Programme (WFP) in Bangladesh indicates that 1 g of Ultra Rice® contains 35–45 µg of additional zinc per gram of raw, milled rice compared to standard rice varieties in Bangladesh. Cooked Ultra Rice® contained 31–40 µg of additional zinc per gram of rice.[19] These zinc concentration levels are higher than those observed for the reduced milling and fertiliser concepts, and are broadly comparable to the upper range reported in the literature on zinc-soaked rice, but less than that obtained in studies done in Bangladesh (GAIN, 2013a).

There is potential for Ultra Rice® to take root in Bangladesh because it could fit with consumer preferences, and price premiums fit broadly with what consumers are willing to pay. Consumer acceptance will ideally remain unaffected because Ultra Rice® grains are designed to be indistinguishable from traditional, polished rice in terms of appearance, aroma, and taste. There have been concerns with consumer acceptance from experiences in other countries (i.e. India) around acceptability of the micronutrient grains and impact on cooking quality. This has been tested by the Bangladesh Rural Advancement Committee (BRAC) and is currently being tested in Bangladesh by WFP; initial

[16] HarvestPlus, 2009; Dalberg analysis.
[17] Interviews with seed companies.
[18] Interview with HarvestPlus Bangladesh.
[19] Interview with PATH-WFP Ultra Rice® project in Bangladesh; Dalberg analysis.

results are promising. Convincing consumers to pay the 1–2 Tk per kg premium is estimated to be acceptable. According to the GAIN consumer survey, this falls at the upper end of the premium that consumers would be willing to pay for nutritious rice and it could be further leveraged through a targeted awareness campaign.

The primary challenges with this concept are building miller capacity to blend Ultra Rice® and ensuring a secure supply chain to import and procure the micronutrient kernel to add it into the milling process. This process would require many millers in Bangladesh to purchase blending equipment to mix the micronutrient grains and standard rice in a fixed ratio. While some of the larger mills already have this equipment, the upfront cost for millers who don't already have it is significant. However, many millers did express interest in pursuing a process that could enable them to differentiate their products, but they would have to be convinced of the market demand. In addition, Ultra Rice® is manufactured outside Bangladesh and port authorities and customs officials in Bangladesh currently have limited understanding of the regulations surrounding it.[20] As a result, they could delay or even bar entry of the product into Bangladesh. It will be important to educate relevant government authorities so that regulatory and bureaucratic challenges are minimised.

[20] Since the time of this study, NutriRice™ production has been established in Bangladesh. This process uses hot extrusion technology, which is generally more expensive than the cold extrusion technology used by UltraRice®, and the price premium is not confirmed.