Rural Bangladeshi Consumers' Willingness to Pay for Rice with Improved Nutrition via Zinc Biofortified Rice and Decreased Milling Practices

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Abstract

Zinc deficiency is a severe public health issue in Bangladesh. We examine the effects of nutritional information on rural consumers' willingness-to-pay (WTP) for two ways to address zinc deficiency—biofortification of rice with increased zinc content (an invisible trait) and low-milling that gives rice grains a distinctive light brown color (a visible trait) and sets it apart from the culturally preferred highly-milled white rice grain. Results of our economic experiments suggest that with nutritional information, consumers are willing to pay a premium of 6% for zinc biofortified rice compared to non-biofortified rice. However, results confirm the strong preference for high milled rice of Bangladeshi consumers who discounted less-milled rice by 14%. This discount was reduced to 10% with information, suggesting a positive effect (4%) of information on WTP for less-milled rice. We also find that consumers' WTP for these two high-zinc rice grains was positively correlated with being a female, more education, and belonging to households with a major income source from non-farm activities and with children under five years of age. Results point to the importance of nutritional awareness campaigns for increasing zinc biofortified and low-milled rice consumption and guiding the targeting strategy for such campaigns.

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1. Introduction

Micronutrient malnutrition, also known as ‘hidden hunger’, is one of the most prevalent forms of malnutrition, estimated to affect two billion individuals worldwide prior to the COVID-19 pandemic. (FAO, IFAD, and WFP, 2015). Hidden hunger disproportionally affects rural populations of developing countries as a majority of food intake is from staple crops. Zinc deficiency, one of the main forms of hidden hunger, is considered a severe public health issue in Bangladesh with 30 percent of the population at risk of inadequate zinc intake (Wessells et al., 2012). Zinc is essential for proper physical and cognitive development in children and adults. Additionally, zinc is crucial for proper immune system development and resiliency, which decreases susceptibility to infections such as diarrhea and pneumonia, a leading cause of child mortality in the developing world (Black et al., 2013), and most recently to novel infectious diseases like COVID-19. In Bangladesh, 94 percent of women of childbearing age (WOCBA) are at risk of inadequate zinc intake (Rahman et al., 2016) while 57 percent suffer from zinc deficiency (ICDDR,B 2013). Moreover, 45 percent of preschool-age children are zinc deficient (Rahman et al., 2016).

Increased zinc intake can most readily be attained by improved dietary quality that meets both caloric and nutritional requirements. However, much of the world cannot access or afford a diet of micronutrient-rich foods like fruits, vegetables, and animal-source foods; it is estimated that 3 billion people, pre-COVID 19 pandemic, cannot afford a healthy diet (FAO, IFAD, UNICEF, WPF, WHO, 2020). Therefore, not surprisingly, it has been found that six of the top ten global burden of disease is det-related (Murray et al., 2020). Even when these foods are available, they are often allocated to men or adolescent boys in the household (Gittelsohn and Vastine, 2003; Herrador et al., 2015), even though WOCBA and children under five have higher biological needs for micronutrients (Black et al., 2013; Branca et al., 2015; Ruel-Bergeron et al., 2015; De-Regil et al., 2016). To date, the majority of interventions used to address general hidden hunger have been food fortification (during the processing stage) and supplementation, though with limited success in rural areas (Narayan et al., 2019).

In this paper we assess Bangladeshi consumers' willingness-to-pay (WTP) for two alternative, low-cost, and relatively new rice interventions intended to address zinc deficiency: (1) zinc biofortified rice and (2) less-milled rice. We measure the impact of varying amounts of information for these two interventions on 576 consumers' WTP through conducting economic experiments using the Becker-DeGroot-Marschak (BDM) mechanism.

This paper makes several important contributions to the literature. First, we measure consumer demand for a zinc biofortified crop and its specific zinc genetic grain trait. While numerous studies have explored the acceptance and WTP for nutritionally enhanced foods made with genetic crop traits, most have been for visible traits, such as vitamin A in maize, cassava, and sweet potato (Stevens and Winter-Nelson, 2008; Naico and Lusk, 2010; Chowdhury et al., 2011; De Groote et al., 2011; Meenakshi et al., 2012; Banerji et al., 2013; Oparinde et al., 2014). Fewer studies have elicited consumer WTP for invisible crop traits, and those primarily examined iron beans and iron pearl millet (Oparinde et al., 2015; Banerji, et al. 2015; Perez et al., 2014). To our knowledge, no study has evaluated consumer WTP for the zinc genetic trait in any crop, making this study the first of its kind. One study has been conducted though it focused on producer WTP for zinc rice seed (Valera et al., 2019). Further, as shown in the aforementioned sentence, the majority of work to date on rice in Bangladesh has focused on producer decision-making (Spielman et al., 2017; Ortega et al., 2019; Ward, 2015), and less focus on consumption preferences so this paper will push forward the research in this respect.

Another contribution of this study is the focus on WTP for processing techniques where the main objective is to improve nutritional content. A variety of WTP studies regarding food processing have been conducted; however, the focus is often on consumer interest in processing that preserves food attributes (Olsen et al., 2010), or enhances food safety (Tonsor et al., 2009; Ortega et al., 2011; Walke et al., 2014). Additional research has been done on WTP for value-added products (Michel et al., 2011). Specific to rice, the Africa Rice Center has researched consumer demand for improved processing techniques (such as parboiling, milling, cleaning, and grading), but the focus has been to increase the local rice quality and raise its competitiveness against imported rice in Africa (Demont and Ndour, 2015).

The rest of this paper is organized as follows: Section 2 provides a background on zinc biofortified rice and rice processing practices in Bangladesh, Section 3 describes the study's conceptual framework, and Section 4 shares data and sample descriptive statistics. The estimation strategies and empirical models used, along with analysis results are described in Section 5. Section 6 concludes and discusses policy implications from our findings.

2. Background

2.1 Rice in Bangladesh and Zinc Biofortified Rice

Rice (*Oryza sativa* L.) is the staple food crop in Bangladesh. In the typical Bangladeshi diet, rice contributes 62 percent of daily calories (BBS, 2011) with per-capita daily rice consumption averaging 472 grams (FAO, 2019). Rice is typically consumed at least twice daily with rural areas often consuming rice in every meal and as an ingredient in snack foods. Most of this rice is sourced domestically as Bangladesh produces approximately 34,500 rice-milled-equivalent (RME) million metric tons (MMTs) per year, imports another 500 MMTs of rice, and exports roughly 2 MMTs of RME each year (FAO, 2019). Further, rice is important as an agricultural crop as rice covers approximately 75 percent of all cropped land in the country and in the majority of the country, the crop can be cultivated in both the rainfed and irrigated growing seasons (BBS, 2017).

Biofortification, the conventional breeding of staple food crops to improve their nutritional content, is now considered as a proven and scalable strategy to address hidden hunger. Biofortified crops are bred to have the same agronomic and consumption attributes as the most popular varieties in a given agro-ecological zone (Bouis and Saltzman, 2017). In a global prioritization index for biofortified crop development and delivery across 128 countries in Africa, Asia, and Latin America, Bangladesh ranked number one for the suitability of zinc biofortified rice based on the country's production and consumption of rice in addition to their zinc deficiency status (Herrington et al., 2019). Zinc biofortified rice was first introduced in the country in 2013 and delivers 70 percent more zinc than common rice varieties, at the same level of milling. Zinc rice can provide up to 60 percent of daily zinc needs when processed and cooked using typical Bangladeshi consumption patterns (Andersson, 2017). Eight zinc rice varieties have been developed through a partnership between the CGIAR's HarvestPlus Program, the International Rice Research Institute, the Bangladesh Rice Research Institute, and the Bangabandhu Sheikh Mujibur Rahman Agricultural University and have been delivered in 62 of the 64 national districts (Lividini, forthcoming). According to HarvestPlus' estimates, 1.9 million farming households (13 percent of all rice-farming households) were growing zinc biofortified rice in 2020, translating to an estimated 10 million people consuming zinc biofortified rice (HarvestPlus, 2021).

2.2 Typical Processing Techniques and Nutrition Retention

Processing impacts the degree of zinc retention in rice. Rice is harvested as paddy (rough rice) which consists of a husk layer covering the caryopsis (brown rice). Typically, the husk is removed to produce brown rice. The brown rice is milled at various levels (degrees) to remove the outer layers of the caryopsis, to produce white rice (Muthayya et al., 2014; Juliano and Tuano, 2019). In Bangladesh and other regions of South Asia and West Africa, paddy rice undergoes an additional step of parboiling before being milled. Parboiling involves the soaking and steaming of paddy rice, at different temperatures, which can reduce the number of broken grains that occur during milling (Tomlins et al., 2004). Parboiled rice is also preferred in Bangladesh due to its longevity (less spoilage), digestibility, and reduced stickiness (Jaim and Hossain, 2012). While zinc is contained in the endosperm of the grain and, therefore, is mostly protected during milling, this is not the case if paddy rice is first parboiled (Taleon et al., 2018). During the parboiling process, zinc moves from the endosperm towards the bran of the kernel, which makes it more vulnerable to being removed during milling (Taleon et al., 2020).

While less-milled rice is often consumed in rural areas due to its lower costs, highly-milled (white) rice is the most popular rice in urban areas (Custodio et al., 2016) and even those eating less-milled rice prefer to eat white rice (GAIN, 2016). White rice is produced by milling the grain to the highest degree possible (approximately 15% milling level) to ensure most of the aleurone layer is removed (IRRI, 2019). In a recent study conducted in Bangladesh, zinc concentration was measured for parboiled rice at the lowest milling level of 7.5 percent, and the highest milling level of 15 percent. The analysis showed that the low-milled grain retained almost 200% more zinc than the highly-milled grain (Taleon et al., 2018). In addition to zinc loss, other vitamin and micronutrients are also lost during a high degree of milling (Muthayya et al., 2014).

The traditional rice milling methods in Bangladesh, the *dheki* hand method or the Engelberg machine that removes the rice husks, embryo, pericarp and some aleurone, mills the grain to around the 7.5 percent level. However, automatic rice mills are increasing in number throughout the country and traditional mills are disappearing as it becomes less expensive to send grain to automatic rice mills (Reardon et al., 2014). The automatic rice facilities mill upwards of 16 percent and double-polish the grain, which while increasing the grade and price premium of the rice (Reardon et al., 2014; Khan and Murshid, 2018) produces rice with minimal nutritional content.

3. Methodology

3.1 Experimental Design and Conceptual Framework

The experiment presented in this study is designed to assess consumers' WTP for rice grain that has increased zinc content and to assess whether the WTP for this nutrition trait differs by the two approaches of increasing zinc content--biofortification versus low-milling processing techniques. This study tests these differences with and without the information on zinc nutritional benefits associated with biofortification and low-milling. Two rice varieties representing non-biofortified (NB) rice (BRRI dhan28) and biofortified (B) rice (BRRI dhan42) are used in this study.[4] To retain nutritional value, the biofortified rice is milled at 7.5 percent, which represents low-milling (LM) level.[5] The non-biofortified rice is milled at two levels – 7.5 percent (LM) and the more popular 15 percent (high-milling level, HM). Thus, the experiment includes three rice grain types, consisting of two different rice varieties and two levels of milling—non-biofortified BRRI dhan28 at high-milled level (NBHM), non-biofortified BRRI dhan28 at low-milled level (NBLM), and biofortified BRRI dhan42 at low-milled level (BLM). The experiment follows a between-subject design and consists of three groups—Treatment group 1 (TG1) that received information on zinc biofortified rice, Treatment group 2 (TG2) that received milling nutrition information, and a control group that received no information.

The WTP experiments elicit information regarding respondents' WTP for the aforementioned rice grain types. We utilize the Becker-DeGroot-Marschak (BDM) (Becker, DeGroot, and Marschak 1964) method, which is an incentive-compatible single response procedure used in experimental economics to measure consumer WTP. In the BDM mechanism, a respondent submits a bid for a good being auctioned, which in this study is 1 kilogram of each rice grain type. The respondent does not bid against other individuals as in a traditional auction, but bids against a random market price which is drawn from a distribution established *ex-ante*. If the respondent's bid is greater than the market price drawn, then s/he pays the randomly drawn market price and receives the good of interest. Alternatively, if the respondent's bid is less than the market price no transaction occurs.

The respondent's true WTP for a unit of the good being auctioned is defined as the price that induces a utility indifference between winning and not winning the unit of the good. Rational behavior under the

[4] The non-biofortified rice, BRRI dhan28, is the most popular rice grain in Bangladesh in the season in which the study was conducted so therefore, it serves as the experiment's benchmark grain. BRRI dhan42 was selected as the biofortified rice used as it most closely resembles the grain characteristics of BRRI dhan28 (Tiongco and Hossain, 2015; Lividini et al., forthcoming).
[5] Though adding a zinc biofortified rice milled at 15 percent seems like a natural addition to the experiment, we did not present this grain option to consumers as milling at 15 percent negates and removes the added genetic zinc content bred into the grain.

BDM mechanism is for the respondent to place a bid equal to their WTP (Lusk and Shogren, 2007). In the case of individuals bidding on multiple goods, as in our case, one of the bids is selected at random and serves as the binding bid such that only one good's bid is compared against a market price for that particular good. The difference in the bids between BDM experiments with and without information reveals the premium, or discount, due to the different rice grain attributes as perceived by the consumer.

The BDM elicitation method varies between either endowing respondents with a good and having them bid to upgrade that good, known as "endow and upgrade", or asking participants to offer full bids for a particular good (Lusk and Shogren, 2007). We use the full bidding method since we are interested in capturing total WTP for each product. At the start of the study, each participant received a participation fee of 500 Bangladesh taka (BDT), the equivalent of US $6.04.[6] As we included participation fees in the study, it should be noted that there is a possibility of inflated WTP bids due to "windfall" income effect, though the literature suggests the effect has been mixed (Loureiro et al., 2003; Corrigan and Rousu, 2006; Meenakshi et al., 2012; Oparinde et al., 2016).

Prior to the experiment, trained enumerators explained the BDM procedure in one-on-one settings to respondents. To ensure understanding, a practice round was conducted with common crackers. Respondents were allowed to ask clarifying questions on the instructions and experimental procedure. Following this, if the respondent had been randomly assigned to either of the two treatment arms, they listened to a respective one-minute informational audio clip on zinc nutritional enhancement via zinc biofortified rice (TG1) or via decreased milling practices (TG2). Those that were not randomly assigned to TG1 or TG2, served as the control group. To mimic market settings, in all groups, one kilogram of the three uncooked rice grains (NBHM, NBLM, and BLM) were placed in randomized order in front of the respondents in equal sized clear containers without labels but with different colored lids: red, orange, and

[6] The exchange rate at the time of the experiment was approximately 82.73 Bangladesh takas (BDT) to 1 USD. The participation fee of 500 BDT is approximately equal to a daily wage for the study locations at the time of the experiment plus the average price for one kilogram of rice.

green. The invisible zinc attribute cannot be detected in the BLM rice, but low-milled rice is easily identifiable by its brown color compared to high-milled rice which is white. In the TG1, both the video and the enumerator identified the BLM rice from the NBLM and NBHM rice. Similarly, in TG2, the video and the enumerator identified the two low-milled rice grains. Consumers were allowed to touch and smell the grain during the bidding process.

In TG1 and TG2, after listening to the audio clip, respondents submitted bids for each of the three rice grain types but were told that only one bid would be binding. In the control group, no audio clips/information was provided, so respondents submitted their bids after completing the practice round. The distribution of the randomly selected market price, uniform between 28 and 50 BDT/kg of rice, was based on current local market prices. Respondents were not informed of this price range nor were their bids censored on lower or upper bounds. Respondents were simply told that the prices were based on current rice prices from their local market. To select the binding bid, participants drew one of three colored die (red, orange, or green) from an opaque bag which corresponded to the lid color of each of the three rice products. Next, the participant drew one "coin" from another opaque bag of market prices. Then the enumerator compared the respondent's bid to the market price they drew and transactions were carried out according to the rules of the BDM mechanism. After completing the experiment, respondents completed a short survey questionnaire.

3.2 Empirical Strategy

We use regression analysis to examine the effect of the information treatment on consumers' WTP bids. Since the experiment was between subjects, we estimate the treatment effect via Pooled Ordinary Least Squares (POLS) method. Equation 1.1 is a parsimonious specification intended to estimate only the information treatments' effect in explaining WTP bid variation ($\text{i.e.}, \text{coefficient } \beta_3$). We test the robustness of the treatment effect size by incorporating control variables ($\boldsymbol{X_i}$) in equation 1.2, and the interaction of the treatment with a subset of control variables (vector $\boldsymbol{Y_i}$) in equation 1.3. Our specification for the linear panel data model used is:

$$Bid_{ijt} = \alpha + \beta_1 P_j + \beta_2 T_t + \beta_3 (P_j \ x \ T_t) + \ u_{it} \tag{1.1}$$

$$Bid_{ijt} = \alpha + \beta_1 P_j + \beta_2 T_t + \beta_3 \big(P_j \ x \ T_t\big) + \ \boldsymbol{\eta X_i} + u_{it} \tag{1.2}$$

$$Bid_{ijt} = \alpha + \beta_1 P_j + \beta_2 T_t + \beta_3 \big(P_j \ x \ T_t\big) + \ \boldsymbol{\eta X_i} + \ \boldsymbol{\gamma}(\boldsymbol{T_t \ x \ Y_i}) + \ u_{it} \tag{1.3}$$

where P_j represents the three rice products (NBLM=0, BLM=1, and NBHM=2), T_t represents the information treatment (information on zinc biofortified rice=1 and information on low-milling=2). Each of these three equations are estimated separately for the two information treatments. The Bid_{ijt} is the WTP for consumer *i* for the nutritionally enhanced product (P_j) relative to the counterfactual. In the case of the zinc biofortification treatment (t=1), we compare BLM (j=1) to the NBLM (j=0). For the information on low-milling (t=2), we compare NBLM (j=0) to the NBHM (j=2). The $\boldsymbol{X_i}$ represents a vector of respondent characteristics and experiment controls. $\boldsymbol{T_t \ x \ Y_i}$, is a small vector of interaction terms between the treatment variable and selected respondent characteristics based on a priori hypotheses and previous literature. Respondent characteristics included in $\boldsymbol{Y_i}$ are the number of children under five years of age in the household, the household's per-capita monthly income, the respondent's years of formal education, and in the case of the BLM vs. NBLM regressions, if the respondent was previously aware of zinc biofortified rice varieties. Finally, u_{it} is the idiosyncratic error term.

Next, we use regression analysis to examine WTP premiums (and discounts) by comparing (1) BLM versus NBLM rice, and (2) NBLM versus NBHM rice. The value of Equation 2, below, lies in identifying additional determinants of premiums/discounts of BLM and NBLM, beyond the information treatment itself, which can be used for nutritional awareness campaign targeting to maximize finite resources (time, money, human capital, etc.). Our marginal OLS WTP estimation can be represented as:

$$PremBid_i = \alpha + \beta T_t + u_{it} \quad (2.1)$$

$$PremBid_i = \alpha + \beta T_t + \boldsymbol{\eta X_i} + u_{it} \quad (2.2)$$

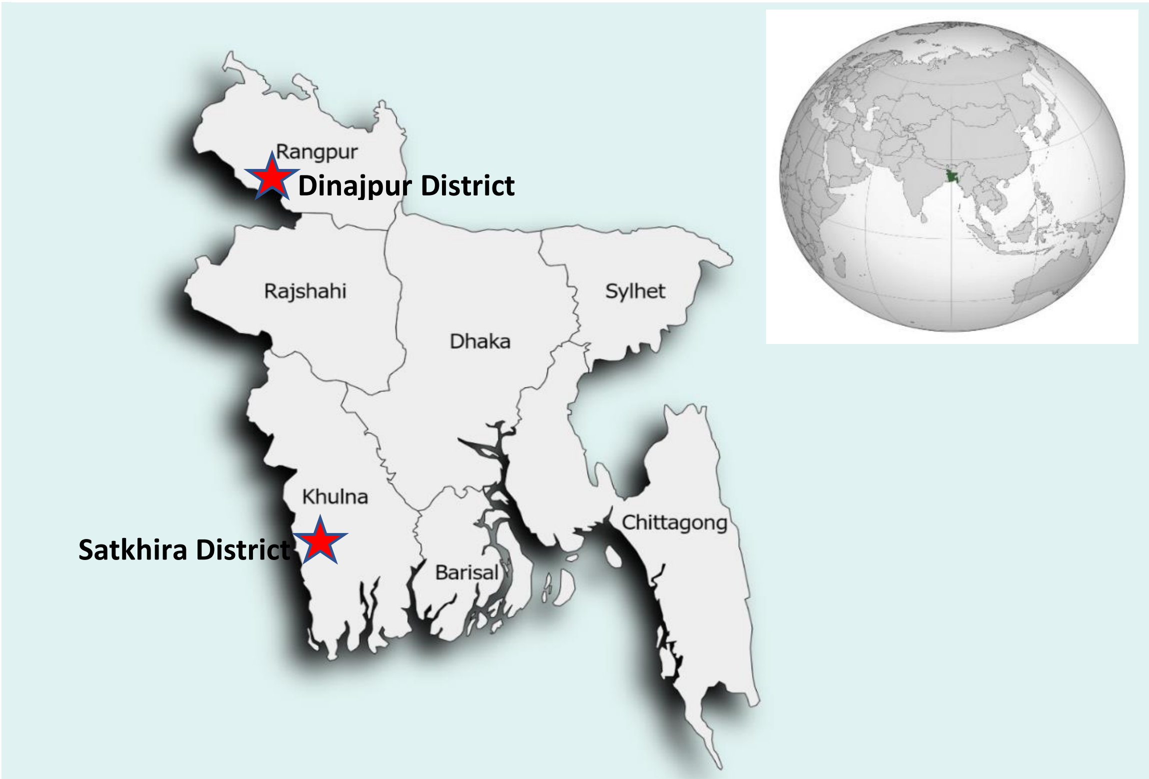
$$PremBid_i = \alpha + \beta T_t + \boldsymbol{\eta X_i} + \boldsymbol{\gamma}(\boldsymbol{T_t \ x \ Y_i}) + u_{it} \quad (2.3)$$

where $PremBid_i$ is estimated as individual i's difference in WTP bids for a nutritionally enhanced product (either BLM rice in case of treatment 1 or NBLM rice in case of treatment 2) against its counterfactual (i.e., NBLM rice in case of treatment 1 or NBHM rice in case of treatment 2). The $\boldsymbol{X_i}$ represents a vector of respondent characteristics and experiment controls. $\boldsymbol{T_t \ x \ Y_i}$, is a small vector of interaction terms between the treatment variable and select respondent characteristics based on a priori hypotheses and previous literature. Respondent characteristics included in $\boldsymbol{Y_i}$ are the number of children under five years of age in the household, the household's per-capita monthly income, and the respondent's years of formal education. Finally, u_{it} is the idiosyncratic error term. In these models, coefficient β measures the effect of the information treatment on consumers' WTP a premium (or discount) for the nutritionally enhanced trait (either zinc biofortification or low milled rice).

3.3 Data

Data was collected through collaboration with the CGIAR's HarvestPlus Program and the Bangladesh Rice Research Institute (BRRI). Ethical clearance was received from IFPRI's IRB and locally from BRRI. A total of 576 rice consumers, split evenly between Dinajpur district in the north and Satkhira district in the south, participated in the study.[7] Dinajpur and Satkhira districts were specifically selected as study locations as Dinajpur is a surplus rice producing region with many automatic rice milling facilities while Satkhira is a net purchaser of rice and has few automatic rice mills.

Figure 1: Map of Bangladesh and Study Locations



*Sources: mapsland.com and paintmaps.com

[7] Within Dinajpur, data collection occurred in Parbatipur, Birganj, and Sadar upazilas. In Satkhira, data was collected in Kaliganj, Kolaroa, and Satkhira Sadar upazilas.

The study was targeted to the main household decision-maker for rice purchases. In our sample, respondents are 93% male and, on average, 42 years old (Table 1). Approximately half of the respondents' main income source is through agricultural work, and on average, they have five years of formal education. On average, the per-capita household consumption of rice for our respondents is 150 kg per year. Respondents vary in the frequency of rice market purchases – 12% purchase rice on a daily basis while 34% of respondents purchase on a monthly basis, or less frequently. Additional sample statistics are included in Table 1.

Table 1: Sample characteristics and balancing test

Variable	Control (N=192)	Treatment 1 (Biofortification) (N=192)	Treatment 2 (Low-milling) (N=192)	P-value of Mean Comparison
Male (%)	94.8 (22.3)	92.7 (26.1)	92.7 (26.1)	0.638
Household Head (%)	84.9 (35.9)	86.5 (34.3)	84.9 (35.9)	0.882
Age (years)	41.2 (12.7)	41.9 (13.3)	41.4 (13.3)	0.853
Years of formal education	5.1 (4.8)	5.1 (4.7)	5.3 (4.8)	0.870
Main occupation is farming[2] (%)	52.6 (50)	51.6 (50.1)	52.6 (50)	0.973
Household size	4.8 (1.6)	4.7 (1.7)	4.8 (1.6)	0.934
No. of children under 5 y.o. in HH	0.4 (0.4)	0.4 (0.6)	0.4 (0.6)	0.585
No. of WOCBA[3] living in HH	1.5 (0.8)	1.4 (0.7)	1.5 (0.8)	0.515
HH's per-capita yearly rice consumption (in 10kg)	15 (3.9)	15.3 (4.2)	15.2 (3.6)	0.747
HH purchases rice more than 1/week (%)	29.2 (45.6)	33.3 (47.3)	31.8 (46.7)	0.6750
HH purchases rice 1/week or 2/month (%)	37.5 (48.5)	30.7 (46.3)	35.4 (47.9)	0.3615
HH purchases rice 1/month or less often (%)	33.3 (47.3)	35.9 (48.1)	32.8 (47.1)	0.788
HH's per-capita monthly income (in BDT)	2120.7 (1642.1)	2053.9 (1484.5)	2070.1 (1590.8)	0.910
Aware of zinc biofortified rice varieties (%)	8.3 (27.7)	9.9 (29.9)	13 (33.7)	0.310

Source: author's data.

Note 1: Standard deviations are presented in parentheses following sample mean estimates.

Note 2: Included in this category are both self-employed farmers and farm laborers on another's farm.

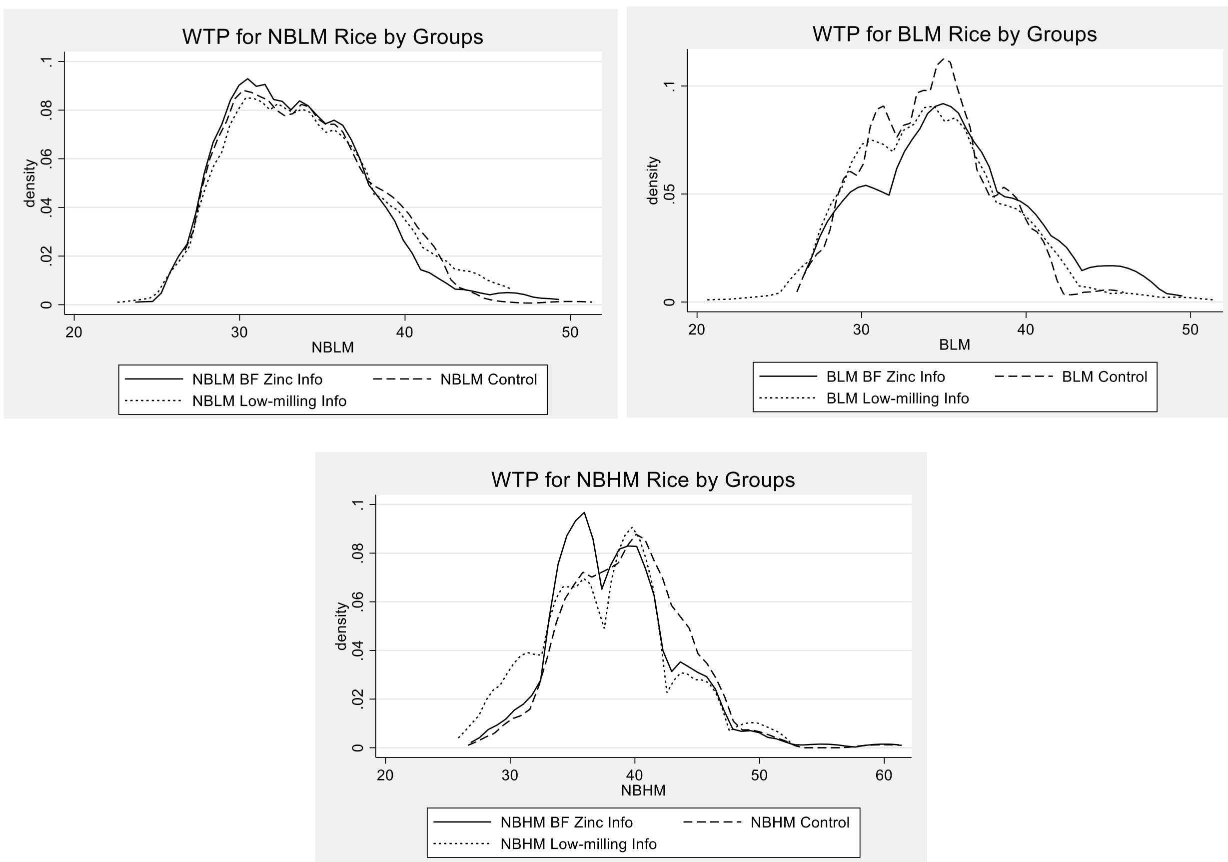
Note 3: WOCBA: females ages 15–49, as defined by the World Health Organization.

4. Results and discussion

4.1 WTP for Nutritional Traits

The distribution of WTP bids by control and treatment groups is presented in Figure 2 below.

Figure 2: Kernel density for (1) NBLM Rice WTP, (2) BLM Rice WTP, and (3) NBHM Rice WTP



The mean bids for the three products suggest a strong preference for NBHM, which is currently the most preferred type of rice grain consumed. Under all three scenarios, consumers' WTP for 1 kg of NBHM is about 4–5 BDT more than the other two nutritionally enhanced rice grains (Table 2). In comparing WTP bids, we find consumers place a 14% premium ($p<0.001$) on NBHM rice compared to

NBLM rice when no information is shared about milling's impact on nutrition. Further, when information is shared about the negative effect of milling on nutrition, the premium declines to 9.9% (p-value<0.001) for the preferred NBHM grain compared to the NBLM grain (translating to a treatment effect size for milling information of 4.1%). Results also show that without information on the zinc biofortified variety, there is a small difference (p<0.10) in consumers' WTP bid for the two low-milled rice--BLM and the NBLM such that a 1.1% premium exists for BLM rice. However, when information is shared on increasing zinc intake via zinc biofortified rice, consumers were willing to pay a 5.8% price premium for BLM rice over NBLM rice (p-value<0.001). Information on zinc biofortified rice increased WTP for BLM rice by 4.6% over NBLM.

Table 2:Willingness to Pay (WTP) for rice types (BDT/1kg) and their traits

	Rice type	Statistic	Control Group * (N=192)	Treatment 1: Zinc Biofortified Information (N=192)	Treatment 2: Milling Nutrition Information (N=192)
Mean WTP	Non-biofortified,	Mean	$33.8^{a, \lambda}$	$33.5^{b, z}$	34.1^{c}
	low-milled variety (a)	St. Deviation	(4.1)	(4.2)	(4.4)
	Biofortified,	Mean	$34.2^{x, w, \lambda}$	$35.5^{b, q, t, x}$	$34.2^{q, s}$
	low-milled variety (b)	St. Deviation	(3.7)	(4.7)	(4.4)
	Non-biofortified,	Mean	$39.4^{a, w, y, \gamma}$	$38.5^{t, z, \gamma}$	$37.8^{c, s, y}$
	high-milled variety (c)	St. Deviation	(4.6)	(4.8)	(5.2)
WTP for traits	Nutrition (Zinc) via biofortified genetic trait (b-a)	BDT/1kg	0.4	1.9	
		St. Deviation	(2.9)	(4.1)	
		%	+1.1	+5.8	
	Nutrition via decreased milling (a-c)	BDT/1kg	-5.5		-3.7
		St. Deviation	(3.1)		(4.8)
		%	-14.0		-9.9

Source: Author's estimation from experiments, Bangladesh (2018–2019).

* Note that rice types in the control group were not known (labeled) to the respondents at the time of bidding. Also, zinc is an invisible seed trait so unless told, respondents could not differentiate which variety was high zinc.

[a,b,c,q,s,t,w,x,y,,z] Numbers with matching English letters denotes that the differences in raw WTP bids between those specific groups are statistically significant at $p < 0.01$.

[λ, γ] Numbers with matching Greek letters denotes that the differences in raw WTP bids between those specific groups are statistically significant at $p < 0.10$.

Next, we examine the effect of the information treatment on consumers' WTP for the two nutritionally enhanced rice products. Results for zinc biofortified rice are presented in Table 3 and for low-milled rice in Table 4. We find that Bangladeshi consumers are willing to pay a significant premium for zinc biofortified rice after exposure to information on zinc biofortified rice (TG1). Results from this analysis match findings from the mean WTP bids (Table 2) and show respondents are willing to pay a premium of 1.55 BDT for BLM rice compared to NBLM rice after receiving zinc biofortified rice information (represented by variable: received zinc biofortified info x BLM rice product), (Table 3). This estimated treatment effect is robust after controlling for consumer and experiment characteristics and interaction effects (columns 2 and 3, Table 3).

Further evaluating cross-effects of receiving zinc biofortified rice information and additional covariates, in column 3, we find a positive WTP for each additional year of formal education attained by the respondent, which outweighs the negative and significant impact on consumer WTP of increases in respondents' formal education when no information is received. Aside from information exposure cross-effects, respondents' bid increases with per-capita household monthly income while bids decrease as respondents age, and if they participated in one of the morning sessions of the experiment.

Turning now to the same models for NBLM versus NBHM rice (Table 4), we find that after receiving the information on the nutritional benefits of low-milling, Bangladeshi consumers' WTP for low-milled rice increased by BDT 1.78/kg relative to NBHM. This estimated effect of the information treatment is statistically significant and robust across model specifications (Table 4).

Statistical differences in mean WTP bids between NBLM and NBHM rice without information, and mean WTP bids between NBHM rice with and without information, support findings in Table 2. Further evaluating cross-effects of receiving low-milling nutrition information and additional covariates, in column 3, we find a negative WTP for NBLM rice as the respondent's household monthly per-capita income increases, which is counter to the effect of income when the respondent did not receive information. Aside from information exposure cross-effects, respondents' bid for NBHM rice decreases if they participated in the morning session.

Table 3: Consumers' WTP for biofortified rice: Results for BLM versus NBLM WTP

	(1)		(2)		(3)	
Variables	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error
Biofortified Rice Product (BLM)	0.385*	0.208	0.385*	0.210	0.385*	0.211
Received Biofortified (BF) Zinc Info	-0.297	0.424	-0.276	0.418	-0.871	0.785
Received BF Zinc Info x BLM Rice Product	1.552***	0.363	1.552***	0.366	1.552***	0.367
Socioeconomic						
Age	--	--	-0.023	0.016	-0.027*	0.016
Female	--	--	-0.370	0.861	-0.095	0.884
HH size	--	--	-0.062	0.128	-0.033	0.125
No. of children in HH 5 years old and under	--	--	0.656*	0.360	0.736*	0.438
No. of years of completed education	--	--	0.011	0.048	-0.114*	0.062
Household per-capita monthly income	--	--	0.264*	0.137	0.416***	0.158
Main Occupation: Farming	--	--	-0.473	0.390	-0.420	0.387
Resides in Dinajpur District	--	--	-0.107	0.408	-0.079	0.410
Rice Behavior						
HH per-capita yearly rice consumption (in 10kg)	--	--	0.008	0.055	0.010	0.055
HH purchases rice weekly or every two weeks	--	--	0.412	0.504	0.454	0.504
HH purchases rice monthly or less often	--	--	-0.086	0.522	-0.322	0.515
Experiment Controls						
Felt hungry at time of experiment	--	--	0.133	0.378	0.195	0.379
Participated in a morning session for experiment	--	--	-1.087***	0.388	-1.04***	0.382
Cognitive						
Aware of BF rice prior to study	--	--	0.186	0.649	0.012	0.991
Cross-effects of Receiving Zinc Biofortified Info						
x No. of children in HH 5 years old and under	--	--	--	--	-0.219	0.610
x Household per-capita monthly income	--	--	--	--	-0.336	0.268
x No. of years of completed formal education	--	--	--	--	0.264***	0.087
x Aware of BF rice prior to study	--	--	--	--	0.515	1.297

Constant (NBLM rice)	33.844***	0.3	34.786***	1.385	35.043***	1.334
R-Square	0.03		0.0805		0.1004	
Number of observations	768		768		768	
Number of respondents	384		384		384	

Note: Robust standard errors are clustered at participant id level
Statistical significance denoted as follows: * = 0.10 level, ** = 0.05 level, and *** = 0.01 level.

Table 4: Consumers' WTP for low-milled rice: Results for NBLM versus NBHM WTP

	(1)		(2)		(3)	
Variables	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error
Non-biofortified Low-milled Rice Product (NBLM)	-5.516***	0.226	-5.516***	0.228	-5.516***	0.228
Received Milling Nutritional Info	-1.568***	0.501	-1.520***	0.505	-0.145	0.882
Received Milling Info x NBLM Rice Product	1.776***	0.415	1.776***	0.419	1.776***	0.420
Socioeconomic						
Age	--	--	-0.016	0.017	-0.019	0.017
Female	--	--	-0.417	1.002	-0.642	0.995
HH size	--	--	0.042	0.155	0.038	0.151
No. of children in HH 5 years old and under	--	--	0.228	0.370	0.575	0.477
No. of years of completed education	--	--	-0.066	0.049	-0.067	0.071
Household per-capita monthly income	--	--	0.223*	0.140	0.451**	0.180
Main Occupation: Farming	--	--	-0.466	0.441	-0.575	0.444
Resides in Dinajpur District	--	--	-0.362	0.448	-0.427	0.448
Rice Behavior						
HH per-capita yearly rice consumption (in 10kg)	--	--	-0.058	0.063	-0.052	0.063
HH purchases rice weekly or every two weeks	--	--	-0.101	0.526	-0.226	0.535

HH purchases rice Monthly or less often	--	--	0.217	0.529	0.108	0.528
Experiment Controls						
Felt hungry at time of experiment	--	--	0.320	0.435	0.312	0.430
Participated in a morning session for experiment	--	--	-0.802*	0.431	-0.795*	0.433
Cross-effects on Heard Zinc Biofortified Info						
x No. of children in HH 5 years old and under	--	--	--	--	-0.823	0.677
x Household per-capita monthly income	--	--	--	--	-0.486*	0.263
x No. of years of completed formal education	--	--	--	--	-0.007	0.090
Constant (NBHM rice)	39.359***	0.331	41.113***	1.791	40.772***	1.784
R-Square	0.2119		0.2327		0.2399	
Number of observations	768		768		768	
Number of respondents	384		384		384	

Note: Robust standard errors are clustered at participant id level

Statistical significance denoted as follows: * = 0.10 level, ** = 0.05 level, and *** = 0.01 level.

5.2 Determinants of Marginal WTP

Next, we focus on the effect of information treatment and other correlates on consumers' WTP premiums/discounts for the zinc biofortified rice and low-milled rice (Table 5). Results, in columns 2 and 3, of this analysis indicate the presence of BLM price premiums for subjects not receiving zinc biofortified information, if the respondent was female, if the respondent resides in Dinajpur district (the rice-surplus producing district), and increases as HH yearly per-capita rice consumption increases. The results for the respondent residing in Dinajpur is unexpected but potentially respondents residing in a rice-surplus producing region such as Dinajpur are commonly exposed to different rice varieties/attributes in the local market compared to rice-importing regions and are therefore, more willing to try a new rice attribute. A discount for BLM rice was found to exist, without receiving information, if the respondent's main occupation was farming, and for every child under five years of age in the household. Contrary to this, if the respondent received zinc biofortified rice information then we see a bid premium for BLM over NBLM rice for children under five years of age in the household (column 3). Likely, with no detectable difference in the BLM and NBLM rice, in the absence of information, the respondent is focused mainly on meeting caloric needs of household members. However, upon receiving information, the respondent likely values the nutrition aspect of BLM for their children's consumption and factors this aspect into their WTP in addition to meeting pure caloric needs.

In the absence of information, consumers steeply discount NBLM rice compared to NBHM rice (Table 6). NBLM rice receives a premium over NBHM rice for every additional child under five years of age in the household (columns 2 and 3). This finding is intuitive as the household is likely more focused on meeting the caloric needs of the household first and foremost before addressing any specialty rice attributes, purchasing a larger quantity of what is perceived as lower quality grain (NBLM in the absence of information) instead of less quantity of a more expensive grain. Besides children in the household, NBLM rice receives no premium over NBHM rice, without the respondent hearing milling information. Cross-effects, in column 3, show that bid premiums exist for NBLM rice for each additional year of education attained by the respondent, which is counter to the discount existing for NBLM rice with increased educational attainment, when the respondent receives no milling information. One would expect education to be correlated with income and status in a community so as highly-milled rice is the preferred rice for many reasons, a discount for NBLM rice with increasing education makes sense when no information is received. Further, NBLM rice is discounted as the respondent ages, when no information is received. This result is not surprising given likely one's income increases as one ages, one has established preferred consumption choices by experimenting over time making one less likely to deviate from their status quo, and further, age is likely correlated with respect and as stated earlier consuming highly-milled rice is seen as a status symbol.

Table 5: Consumers' Marginal WTP for Biofortified Rice: Results for BLM minus NBLM WTP

	(1)		(2)		(3)	
Variables	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error
Received BF Zinc Info x BLM Rice Product	1.552***	0.369	1.528***	0.367	0.630	0.543
Socioeconomic						
Age	--	--	-0.006	0.018	-0.003	0.018
Female	--	--	1.668*	0.832	1.732**	0.833
HH size	--	--	0.129	0.123	0.104	0.124
No. of children in HH 5 y.o. and under	--	--	-0.302	0.333	-0.836***	0.301
No. of years of completed education	--	--	-0.003	0.051	0.027	0.052
HH per-capita monthly income	--	--	-0.009	0.148	-0.156	0.162
Main Occupation: Farming	--	--	-1.272***	0.357	-1.31***	0.358
Resides in Dinajpur District	--	--	0.729**	0.326	0.724**	0.322
Rice Behavior						
HH per-capita yearly rice consumption (in 10kg)	--	--	0.117**	0.05	0.114**	0.050
HH purchases rice weekly or every two weeks	--	--	0.508	0.492	0.566	0.492
HH purchases rice Monthly or less often	--	--	0.441	0.486	0.483	0.481
Experiment Controls						
Felt hungry at time of experiment	--	--	0.179	0.305	0.202	0.310
Participated in a morning session for experiment	--	--	0.466	0.39	0.491	0.389
Cognitive						
Aware of BF rice prior to study	--	--	-0.203	0.586	-0.562	0.718
Cross-effects on Heard Zinc Biofortified Info						
x No. of children in HH 5 y.o. and under	--	--	--	--	1.102*	0.606
x HH per-capita monthly income	--	--	--	--	0.324	0.220
x No. of years of completed education	--	--	--	--	-0.056	0.083
x Aware of BF rice prior to study	--	--	--	--	0.695	1.262

Constant (BLM minus NBLM rice)	0.385**	0.188	-1.977	1.496	-1.605	1.442
R-Square	0.0458		0.115		0.1285	
Number of observations/respondents	384		384		384	

Note: Robust standard errors are clustered at the block administrative level for all models
Statistical significance denoted as follows: * = 0.10 level, ** = 0.05 level, and *** = 0.01 level.

Table 6: Consumers' Marginal WTP for Low-Milled Rice: Results for NBLM minus NBHM WTP

	(1)		(2)		(3)	
Variables	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error	Est. coeff.	Robust Std. error
Received Milling Info x NBLM Rice Product	1.776***	0.352	1.786***	0.356	-0.004	0.677
Socioeconomic						
Age	--	--	-0.029	0.019	-0.034*	0.018
Female	--	--	0.421	0.745	0.423	0.770
HH size	--	--	-0.014	0.128	-0.012	0.126
No. of children in HH 5 y.o. and under	--	--	0.866**	0.394	0.624*	0.346
No. of years of completed education	--	--	0.007	0.048	-0.161***	0.048
HH per-capita monthly income	--	--	0.02	0.127	0.087	0.099
Main Occupation: Farming	--	--	-0.046	0.377	0.042	0.368
Resides in Dinajpur District	--	--	0.081	0.391	0.016	0.352
Rice Behavior						
HH per-capita yearly rice consumption (in 10kg)	--	--	-0.033	0.05	-0.023	0.052
HH purchases rice weekly or every two weeks	--	--	0.611	0.539	0.583	0.536
HH purchases rice Monthly or less often	--	--	-0.59	0.459	-0.728	0.449
Experiment Controls						
Felt hungry at time of experiment	--	--	0.96**	0.377	0.991***	0.367

Participated in a morning session for experiment	--	--	0.184	0.37	0.249	0.344
Cross-effects on Heard Zinc Biofortified Info						
x No. of children in HH 5 y.o. and under	--	--	--	--	0.546	0.707
x HH per-capita monthly income	--	--	--	--	-0.059	0.233
x No. of years of completed formal education	--	--	--	--	0.329***	0.088
Constant (NBLM minus NBHM rice)	-5.516***	0.221	-4.742***	1.698	-3.884**	1.673
R-Square	0.0457		0.1068		0.1436	
Number of observations/respondents	384		384		384	

Note: Robust standard errors are clustered at the block administrative level for all models
Statistical significance denoted as follows: * = 0.10 level, ** = 0.05 level, and *** = 0.01 level.

6. Policy Implications and Conclusion

This study evaluates rural Bangladeshi consumers' WTP for increased nutrition (zinc) content of their main staple crop – namely rice via two nutrition-sensitive interventions, zinc biofortified rice and low-milled rice. Zinc deficiency is a severe public health concern in Bangladesh and could be alleviated through food-based approaches such as biofortification, food fortification, and consumption of more whole (less processed) grains. Through experiments we (1) estimated the impact of providing nutrition information on consumers' WTP for zinc biofortified rice grain and low-milled rice grain, and (2) assessed additional determinants of marginal WTP for the zinc-dense rice products to aid targeting efforts of nutritional awareness campaigns.

As evidenced by respondents in the information treatment groups showing a greater mean WTP for both the BLM rice and the NBLM rice compared to the control groups, consumers exhibit a preference for rice with increased zinc content. The results indicate a premium exists for BLM rice compared to NBLM upon receiving zinc biofortified rice nutritional information. Taking into account initial differences in consumer WTP between BLM and NBLM rice, the effect size of zinc biofortified rice information accounts for a +1.55 BDT, or 4.6% increase in consumer WTP for one kilogram of BLM rice.

In the control group, there was an expected large difference in mean bid price for the NBLM variety compared to the NBHM rice variety at 33.8 BDT/kg of rice and 39.4 BDT/kg of rice, respectively, as highly milled (white) rice is most preferred by consumers. Without receiving information, the mean discount for NBLM rice was 5.5 BDT/kg, a 14 percent discount. However, with information on increased nutrition (zinc) content through decreased rice milling, the discount between the two varieties decreased to 9.9 percent, translating to a significant low-milling information treatment effect size of 1.78 BDT, or 4.1%.

Findings of this study suggest that to increase consumption of these two rice products, awareness campaigns are needed to (1) educate individuals on the zinc deficiency present in Bangladesh, and (2) inform them about methods of increasing their zinc intake, especially for those in rural areas without access to a diverse diet rich in micronutrients and minerals. Increasing zinc intake through consumption of biofortified rice could be a viable solution for rural households as individuals respond positively to the varieties yet the price premium is small enough to keep it affordable relative to the average rural household's rice consumption spending. Increasing zinc intake through consumption of less-milled rice varieties will likely take a focused, strategic effort by the government and/or health-related NGOs to change perceptions of less-milled rice in a country that generally prefers highly polished white rice. Such efforts will become more important as the ongoing proliferation of automatic rice mills in Bangladesh will likely continue and make it cheaper for consumers to purchase highly-milled rice.

For effective allocation of resources, our analysis indicates that initial efforts to raise consumer awareness for zinc biofortified rice begin in rice-surplus producing regions as opposed to rice-importing regions. Additionally, nutritional campaigns should target non-farm workers, women, families with children under five years of age, and individuals with higher levels of formal education.

To increase demand for less-milled rice, nutritional awareness campaigns are essential to any outreach efforts. Based on this analysis, it is recommended that awareness campaigns target families with children under five years of age, younger individuals, and those that have achieved greater levels of formal education.

For future research, similar analysis including both biofortified and non-biofortified rice, milled at 11% (a medium-level) would be beneficial. While rice milled at 11% (medium-milled) does not retain as much zinc as rice milled at 7.5% (low-milled), it could be a compromise between low and high milling levels that consumers may be willing to make, as the grain would appear semi-white/polished. Evaluating the cost-savings of consumers purchasing less-milled rice, at 7.5% and 11% levels versus 15%, and teasing out the economic health benefits of increased zinc intake via zinc biofortified rice and/or low-milled rice would be an interesting extension of this study and policy evaluation.

Additionally, it would be informative to evaluate what type and how information is shared to determine how consumer WTP may change based on who is providing the information (a non-descript person versus a trusted public health professional), positive versus negative information framing, and the medium for information sharing (SMS, video, radio, town crier, etc.). Further, this study was conducted in rural areas and similar research in peri-urban and urban areas would be useful in scaling up awareness campaigns to reach urban consumers. Consumers in peri-urban and urban areas may exhibit different preferences than rural consumers due to potentially greater access to diverse foods in markets or better access to and income for supplementation and food fortification.

Looking to the future, there are major efforts underway to explore the efficacy and current value-chain environment to fortify rice in Bangladesh (FFI, 2021). As milling in automatic rice mills becomes more accessible, due to location and lower costs, for rural and peri-urban rice producing households, it is likely that highly-milled rice grain will become even more popular with consumers. If and when this is the case, food fortification of rice in zinc could serve as an effective intervention of increasing zinc content in consumers' diets. Therefore, this study's findings may prove useful as a benchmark for consumer acceptance of zinc-dense rice.

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