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Information, Branding, Certification, and Consumer Willingness to Pay for High-Iron Pearl Millet: Experimental Evidence from Maharashtra, India

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Abstract

In this paper we use sensory evaluation methods and Becker-DeGroot-Marschak mechanism to estimate consumer demand for biofortified high-iron pearl millet (HIPM) in Maharashtra, India. Unlike biofortification with provitamin A, biofortification with iron and zinc, does not change the color of the biofortified crop. Therefore, we test the impact of both nutrition information, and branding and certification, as well as the nature of the brand and of the certifying authority (state level versus international), on consumer demand for HIPM. We find that even in the absence of nutrition information, consumers assign a small but significant premium to the HIPM variety relative to the local variety. This is consistent with consumers' more favorable rating of the sensory characteristics of the high-iron variety. Nutrition information on the health benefits of HIPM increases this premium substantially, and regression analysis reveals that consumers prefer international branding and certification authority to their state-level counterparts.

Keywords: biofortification, high-iron pearl millet, Becker-DeGroot-Marschak mechanism
JEL Codes: C35, C93, D12, D83, Q18

1. Introduction

India has one of the world's highest rates of malnutrition (Gragnaloti et al. 2005; von Grember et al. 2008). Micronutrient deficiencies are especially prevalent, with more than 75 percent of preschool children suffering from iron deficiency anemia and 57 percent having vitamin A deficiency (Gragnaloti et al. 2005). At the same time, a large segment of the Indian population is vegetarian for economic, religious, or personal reasons, and, as is the case in many developing countries, access to diverse diets, food supplements, and commercially marketed fortified foods is limited, due to various economic, infrastructure-related, or institutional constraints. There is an urgent need to improve the quality of the diet of the poor in India to ensure better nutritional outcomes.

One promising strategy for reducing micronutrient deficiencies is biofortification—the process of breeding and delivering staple food crops with higher micronutrient content (Qaim, Stein, and Meenakshi 2007; Bouis et al. 2011; Saltzman et al. 2013). Ex ante studies suggest that biofortification is likely to be a cost-effective public health intervention in rural areas of several developing countries, including India, where a majority of poor households' diets is composed of staple foods (Qaim, Stein, and Meenakshi 2007; Stein et al. 2007, 2008; Meenakshi et al. 2010).

Given the regional and seasonal differences in consumption of staple foods in India, three staple crops are currently being biofortified by using conventional plant breeding methods: high-zinc rice and wheat, and high-iron pearl millet (HIPM). Pearl millet is the first of these biofortified crops to be introduced in India. Prior to the *Kharif* (rainy) season of 2012, sales of a high-iron, improved open-pollinated variety (OPV), named ICTP 8203 Fe, started in Maharashtra, one of the major pearl millet-producing and -consuming states in the country. According to Asare-Marfo et al. (2010), however, only 5 percent of pearl millet farmers in Maharashtra grow improved OPVs, whereas 93.5 percent grow hybrid varieties. Therefore, development of hybrid pearl millet varieties is currently underway, and they are expected to be introduced in 2015.

The success of HIPM varieties depends on whether they are accepted and consumed by the target populations. In this paper we investigate consumers' sensory evaluation and economic valuation of an HIPM variety vis-à-vis a local pearl millet (LPM) variety. Specifically, we study (1) rural consumers' preferences for HIPM grain and *bhakri* (a thick flatbread) relative to the grain and *bhakri* of LPM; (2) the impact of information on the health benefits of HIPM on consumer preferences for the grain and *bhakri* of HIPM; and (3) the impact of the type of HIPM brand and certifying authority (i.e., international versus state-level) on consumer preferences for HIPM. We also examine whether consumers' existing awareness of and trust in state-level and international health and food certification authorities can explain any differences in the impact of these two types of brands and certification (i.e., international and state-level) on consumer acceptance.

In this study we focus on the acceptance of rural consumers for two reasons. First, HIPM varieties are directly targeted for the consumption of rural populations, since they may not have access to other nutrition interventions (e.g., iron-fortified foods and iron supplements) or to all-year-round diverse diets as easily and as frequently as their urban counterparts. And second, in the study areas, while about half of rural pearl millet consumers are also producers of this crop (48 percent in our sample), a significant share of pearl millet consumed at home is purchased from the market (74 percent in our sample), and producer-consumers value pearl millet consumption attributes as much as production attributes in their choice of a pearl millet variety (Asare-Marfo et al. 2010).

The study was implemented in February–March 2012, on a sample of 452 pearl millet consumers in rural areas of three districts of Maharashtra: Ahmednagar, Solapur, and Nashik. These districts were selected based on their high pearl millet consumption and production rates, and also because ICTP 8203 Fe seed sales were going to take place in these three districts in June–July 2012. Through experiments implemented in 12 central locations, sensory evaluation data were collected following protocols from food science literature (Tomlins et al. 2007), and economic valuation (willingness-to-pay [WTP]) data were collected using the incentive-compatible Becker-DeGroot-Marschak (BDM) mechanism (Becker, DeGroot and Marschak 1964) in a setting in which participants made actual purchases of the pearl millet.

The contribution of this paper to the literature is threefold. First, even though several studies have investigated consumer demand for vitamin A-biofortified staple foods, such as orange sweet potato, orange maize, and yellow cassava (e.g., Naico and Lusk 2010; Chowdhury et al. 2011; Meenakshi et al. 2012; Banerji et al. 2013; Oparinde et al. 2014), this is the first consumer acceptance study on a mineral-biofortified crop—HIPM. Because of their beta-carotene content, vitamin A-biofortified crops change color—i.e., the biofortification is a visible trait for such crops. However, crops biofortified with minerals (e.g., zinc and iron) do not change their appearance—in other words, biofortification is an invisible trait for such crops. Therefore, it is important to understand if consumers can differentiate biofortified mineral crops based on their sensory evaluation of them.

Related to this, the second contribution of this study is its evaluation of the impact of branding/labeling and certification on consumer differentiation of and demand for such crops with invisible nutrition traits. Previous studies have investigated the impact of such mechanisms on demand for safer or higher-quality foods, such as fruits and baby food in developing countries (e.g., Masters and Sanogo 2002; Birol et al., forthcoming) and several foodstuffs in developed countries (e.g., Barsky et al. 2003; Loureiro and Umberger 2007). However, to our knowledge, this is the first time such levers are being used to evaluate the acceptance of high-value food made with staple crops in a developing country context.

The final contribution of this study is that, as with Oparinde et al. (2014), study participants were not provided with a participation fee prior to partaking in the BDM mechanism. They paid out of their pockets to make the pearl millet purchases. Lack of participation fee and having to make out-of-pocket payments remove any house money effects—i.e., any urge to spend differently out of windfall income (Clark 2002; Cherry, Kroll, and Shogren 2005). Moreover, lack of participation fee also reduces the perception of a quid pro quo experimenter demand. Therefore, the stated WTP values should accurately reflect participants' true valuations of the pearl millet varieties evaluated in this study (Morawetz, De Groote, and Kimenju 2011).

The rest of the paper is organized as follows: the next section explains the methodology, section 3 presents the empirical results, and the final section concludes the paper with implications of the findings for the development, delivery, and marketing of HIPM varieties in Maharashtra.

2. Methodology

2.1. Experimental Auctions and Sensory Evaluation

In this study we employ the BDM mechanism for the elicitation of consumer WTP for the two pearl millet varieties. BDM is a widely and effectively applied auction mechanism in consumer acceptance analysis in several developing countries (e.g., Hoffmann, Barrett, and Just 2009; Kiria, Vermeulen, and De Groote 2010; De Groote, Kimenju, and Morawetz 2011; Morawetz, De Groote, and Kimenju 2011; Oparinde et al. 2014). In a BDM mechanism, a participant places a bid b for the object on sale; then, a sale price p is drawn randomly from an ex ante established distribution F. If $b \geq p$, the participant wins the object and pays price p for it; if $b < p$, the participant does not win it. The dominant strategy for participants is to put in a bid equal to their WTP (e.g., Lusk and Shogren 2007). (WTP here refers to the maximum that the participant is willing to pay for the object, rather than go without it.)

In this study we also use sensory evaluation methods to investigate whether iron biofortification affects various key consumption traits of pearl millet. We use hedonic rating scales adopted from the food science literature (Tomlins et al. 2007), and we ask consumers to use these scales to rate various key consumption characteristics of grains and *bhakri* of both HIPM and local varieties. These characteristics are determined through previous research (Asare-Marfo et al. 2010) as well as through focus group discussions in the study areas.

2.2. Study Sample and Design

The sample was selected through a two-stage purposive sampling design. First, we selected three districts in Maharashtra—Ahmednagar, Nashik, and Solapur—based on (1) available data on production and consumption of pearl millet, especially of the ICTP 8203 Fe variety (Government of Maharashtra 2009; Asare-Marfo et al. 2010); and (2) information from the HIPM delivery manager and the seed company that will deliver the HIPM variety (ICTP 8203 Fe) on where they will concentrate the delivery/sales activities that would take place prior to the *Kharif* 2012 season (Ashish Wele and Binu Cherian, personal communication, 2012).

Second, in each of these districts, we ranked the blocks according to the proportion of farmland area allocated to pearl millet production, and selected the four blocks with the highest proportions (Government of Maharashtra, 2009). From each selected block, we randomly selected four villages within a 20-kilometer (km) radius from each block's town center, where the central location testing was to take place. Study participants from each village were transported to these central locations. The 20-km distance was decided based on logistical constraints—i.e., time and financial resources. In each village, village leaders and *gram sevak*s (village council staff) were contacted for household listings, from which ten households were randomly selected and equal numbers of male and female household members were invited to partake in the study. Overall, 452 participants were interviewed in 12 central locations across three districts.

The total sample size for this study was determined through power calculations. For a pure binary comparison, between with and without information treatments, we expected the treatment effect to have a (minimum effect size/standard deviation [E/S]) ratio of 1/3 or less. This was based on earlier elicitation studies (e.g., Chowdhury et al. 2011; Meenakshi et al. 2012), and our understanding of the setting. In this context, a treatment effect (of the effect of information on WTP) of 15 percent on the average market price of pearl millet (which was between Rs. 16 and Rs. 20 per kg at the time of the study design), and a standard deviation for WTP of Rs. 10 were reasonable. For the one-tailed test with an E/S ratio of 1/3, with a significance level of 5 percent, and a power of 0.8, we required a sample size of about 110 per treatment. At the end, Group A had about twice the sample size of Groups B and C (229, 110, and 113 respectively). The larger Group A sample size was chosen both to be in line with power calculations for binary comparisons in a three-way relationship, as well as to conduct a separate, within-subject experiment with Group A participants with an objective unrelated to that of the present paper.

The three treatment groups (A, B, C) were designed to investigate the various questions posed in the introduction section. Group A was the control group. Participants in this group were asked to evaluate the sensory characteristics of the two types of pearl millet on a hedonic scale, and to participate in the BDM mechanism to elicit their WTP for the two pearl millet varieties. The participants in this group did not know about the nutritional benefits of the HIPM variety. Such "blind" tests are common for evaluating consumer preferences (likes/dislikes) in the food product development literature.

Participants in Groups B and C watched a simulated video message (infomercial) *before* partaking in the sensory evaluation and the BDM mechanism. The infomercial explained the importance of having sufficient amounts of iron in the diet, especially for vulnerable household members (i.e., children and women of child-bearing age), and explained that compared with the LPM, the HIPM variety could provide the household with higher levels of iron. (The appendix contains the text of the infomercial; the infomercial video is available from the authors upon request.) The infomercial was written, directed, performed, filmed, and edited by the students and professors of the University of Pune, Department of Communication and Journalism.

The two "nutrition information" treatments (Groups B and C) differed in the nature of the HIPM brand and certifying authority. In the infomercial given to Group B, participants were told that "HarvestPlus" was the brand of the HIPM variety, and this variety was certified by an "international health authority" to contain higher levels of iron compared with the conventional varieties. HarvestPlus is the global leader in the development and delivery of biofortified planting material (see www.harvestplus.org), and its logo is often used on biofortified planting material and food packages in several countries. Although biofortified planting materials and foods are not yet certified by international health authorities, efforts are underway to include a definition of biofortification in *Codex Alimenterius*.

In Group C, participants were told that the brand for the HIPM variety was "*Samarth*"—a fictional brand that means strong in Marathi—and that the variety was stated to be certified by the state-level health authority to contain higher levels of iron. The Marathi logo was designed by a student of Maharashtra Institute of Technology, Institute of Design in Pune. This fictional brand is very similar to the currently used "*Shaktiman*" brand, which implies strong man/farmer. Although the *Shaktiman* brand and logo did not exist at the time this study was conducted, the study team was aware of the idea and concept. Therefore, the team chose a similar brand and logo (*Samarth*) for the experiment. Our aim in using these two brands (HarvestPlus and *Samarth*) and certification agents (international health authority and state-level health authority) was to shed light on consumer preferences (if any) for them. The two brands used are presented in Figure 1, and the study protocol is explained in greater detail in section 2.3.

2.3. Study Protocol

The study was conducted in 12 central locations (four locations each in three districts), with the help of enumerators trained extensively in sensory evaluation and BDM mechanism protocols. The central location was a well-known building in the town center, which included wedding halls, government buildings, or schools, depending on the town.

The day before each central location test, supervisors went to the selected villages to get the household listings and to randomly select the households from which participants would be invited to the central location to partake in the experiment. In each household, one adult household member was invited. The sex of the invited household member was alternated to obtain equal numbers of men and women. Invited household members were told that they would be testing different pearl millet varieties, and that we were interested in their evaluation of these varieties. They were told that their participation was entirely voluntary, which meant that they could stop the interview at any point and that their responses would be anonymous. They were also told that they were going to be transported to and from the central location free of charge. Finally, they were also informed that they could have an opportunity to purchase 1 kg of the grain of one of the pearl millet varieties they would be testing, so they might want to bring some money with them.

The day of the study, one designated enumerator made the *bhakri* from the two pearl millet varieties, and kept them in two identical (but labeled) tin containers for freshness. The same enumerator made the *bhakri* in all 12 locations and paid attention to use the same kind of water, cooking utensils, and fuel across all 12 locations to ensure uniformity in *bhakri* characteristics across locations. There were four sessions on the days of the experiment: the first two were Group A (nine participants each), and the last two were Groups B and C, whose order was randomized across the 12 locations. Group A participants were interviewed first, to minimize potential contamination from treatments with information from Groups B and C, since Group A was to be used as the control group. Participants in each group came from one of the four villages selected, and at different times, so as to minimize contamination. Assigning each village to one group facilitated participants' transportation as a group to and from the central location.

For logistical considerations, allocation to treatments was randomized at the village level rather than participant level. Given our overall sample size (about 50 villages with nine individuals per village) and the sample sizes needed for each of the three treatments, there is likely an increase in the minimum detectable effect (MDE) size to standard deviation ratio. With an intracluster correlation coefficient (ICC) between 0.1 and 0.15, the MDE varies between 0.38 and 0.42 of a standard deviation, for comparisons between Group A and either of Group B or C. Since groups B and C have smaller sample sizes, a comparison between them has an MDE of between 0.45 and 0.50 for an ICC in this range.

In all groups, the survey started with various socioeconomic questions that helped collect information on household demographics; pearl millet production and consumption characteristics; households' sources of information about health, nutrition, and new agricultural technologies; and participants' knowledge of iron deficiency and its consequences.

Branding or certification (or some kind of identification) of iron content in pearl millet intervention and target populations' trust in the authority that certifies this invisible trait are expected to have significant impact on the successful scaling up of HIPM as a viable solution for alleviating iron deficiency in India. To study whether such trust could influence consumer acceptance of HIPM, we also collected information on participants' knowledge of, and trust in, state, national, and international agencies that could certify health and nutrition claims of food. (The survey instrument is available from the authors upon request.)

For Groups B and C, these questions were followed by the presentation of the infomercial on video and large-screen TV. There were two versions of the infomercial corresponding to the two treatment groups. Even though both versions contained the same information about the nutritional benefits of HIPM, one presented the HIPM to Group B with the international brand (HarvestPlus) and international health authority certification, and the other presented the HIPM to Group C with a local, state-level brand (*Samarth*) and state-level health authority certification. In each treatment group (B or C), all participants watched the infomercial at the same time on the same TV. The enumerators accompanied their respondents to the TV/video area, to ensure they paid attention to the infomercial and did not discuss the information with each other before, during, or after watching it.

Group A participants partook in the sensory evaluation of the LPM and HIPM varieties, and then in the BDM experiment for eliciting WTP after responding to the socioeconomic questions. Participants in Groups B and C partook in the sensory evaluation and BDM modules after watching the infomercial. For Groups B and C, the two pearl millet types tested were labeled as HarvestPlus/*Samarth* and LPM; for Group A, the two pearl millet types were labeled as A and B, which were randomized across participants. For the sensory evaluation of the pearl millet, participants were asked to rate the various traits of the grain (color and size) and of the *bhakri* (color, taste, layers, and ease of breaking) of the two pearl millet varieties one by one, on a Likert scale ranging from 1—Dislike very much, to 5—Like very much.

Prior to the implementation of the BDM experiments, the enumerators introduced participants to the exercise, and explained the notion of WTP as the maximum participants would want to pay for a given bag of grain, rather than not pay anything and go without the grain. Explanations and illustrations were used to convey that it was optimal to bid their true WTP in a BDM experiment (participant and enumerator instructions are available from the authors upon request).

The structure of the BDM experiment was as follows. Participants were asked to state WTP values for 1 kg each of the two varieties. Following this, each participant selected the "binding" variety by tossing a coin. For this binding variety, the participant was asked to draw a "competing price" by randomly selecting a price strip from a bag that contained 26 price strips (ranging from Rs. 5 to Rs. 30), with a uniform distribution around the average market price of Rs. 18. Participants were informed about the distribution of prices on these price strips when they were being introduced to the BDM experiment. If the participant's WTP for this binding variety exceeded the competing price, the participant would "win" and purchase the grain of this pearl millet variety, and make an out-of-pocket payment for a price equal to the competing price. Otherwise, the participant did not "win" the pearl millet variety and, hence, did not make a purchase. In the entire experiment, there was only one instance in which a participant "won" a variety, but could not make the out-of-pocket payment.

After the BDM game, the interview ended. All of the participants signed a participant register, were given a durable shopping bag and Rs. 50 as a token of our appreciation of their time, and were told not to mention these gifts to participants in other groups so as not to bias others' valuation of the pearl millet varieties.

3. Results

3.1. Sample Characteristics and Treatment Groups

Table 1 reports the key socioeconomic characteristics of participants across the three groups. The age and education level of the participants, as well as the number of vulnerable household members (including children under 3 years of age, lactating and pregnant women, and women of child-bearing age), the land area owned by the household, and the proportion of households producing pearl millet, were similar across the three treatment groups.

However, the sex of the participants, household size, and proportion of households who currently have pearl millet grain at home were significantly different across the three treatment groups. Compared with Group C, groups A and B had significantly more male participants, at a 1 percent significance level. Moreover, compared with the other two groups, Group A participants came from significantly larger households, and a greater proportion had pearl millet grain at home. Across the three groups, the proportions of participants who had heard of anemia and of iron-rich foods were not significantly different; but at roughly 20 percent of the sample, the awareness of this prevalent health issue was not widespread. The differences across treatments displayed in Table 1 are taken into consideration when interpreting the results, and demographic and socioeconomic characteristics are controlled for in the regression analysis.

Table 1 also summarizes the variable “relative trust.” For every individual, this is the ratio of individuals’ average trust score (on a Likert scale of 1–5) for international over local (national and state-level) food and seed certification authorities. Thus a value for relative trust less than 1 indicates lower trust in international relative to national authorities; a value greater than 1 reverses this comparison. Trust scores for local authorities are generally 4 or 5. In contrast, approximately 40 percent of the individuals are substantially unaware of comparable international authorities, lending a score of 3 (neither trust nor distrust) for them. For a large fraction of this subset of individuals, relative trust is therefore less than 1.

3.2. Sensory Evaluation

Table 2 presents the average sensory scores for the grain and *bhakri* of the two varieties evaluated, as well as the comparison of the two varieties’ scores, by treatment group. Even in the absence of information (Group A), HIPM receives higher scores than LPM both for grain color and size and for *bhakri* color and ease of breaking, and receives scores similar to those for LPM for *bhakri* taste and layers. Once participants receive information about the health benefits of HIPM, this variety is rated significantly higher for all sensory attributes evaluated.

Comparisons of the sensory scores of each variety across treatment groups are reported in Table 3. The results reveal that participants in the information treatments (Groups B and C) stated significantly higher scores for HIPM, compared with those in treatment Group A. Comparison of the two information treatments (Group B versus C) reveals similar scores for all sensory attributes evaluated. Therefore, the nature of the brand and certifying authority (i.e., international or state-level) for HIPM has no significant impact on consumers’ sensory evaluation of this variety. Finally, a closer look at the comparison of the LPM sensory scores across treatment groups reveals that information provided in Groups B and C significantly lowers sensory scores for all attributes, with the exception of grain color.

3.3. Willingness to Pay

Consumers' mean WTP for both varieties is reported in Table 4, by treatment group. Table 5 presents the comparison of the WTP values for the two varieties within each treatment group, and Table 6 presents the comparison of the WTP values for each variety across treatment groups.

Overall, the WTP results are in line with the sensory evaluation scores reported above. Even in the absence of information, consumers are willing to pay more for HIPM compared with LPM (Table 4); this difference of 6.5 percent is significant at a 1 percent level. Receiving the nutrition information increases the mean WTP for HIPM by 12 percent relative to Group A, for the international brand and certifying authority (Table 6, Group B versus Group A). For the state brand and certification treatment (Group C), the mean WTP increases by 7 percent relative to Group A. However, the difference in mean WTP for the international versus the state-level brand and certification treatments (Group B versus Group C) is not statistically significant (Table 6).

Therefore, the presence of nutrition information in treatments B and C increases consumer WTP for HIPM significantly, while also significantly reducing their WTP for LPM (Table 6). Several previous consumer acceptance studies have found that information on the nutritional benefits of biofortified varieties not only affects consumer WTP of these varieties positively, but also has a negative effect on consumer valuation of local/control varieties (e.g., Banerji et al. 2013; Oparinde et al. 2014). The combined positive impact of information on WTP for HIPM and the negative impact of information on WTP for LPM results in participants in Group B being willing to pay 32.4 percent more for HIPM relative to LPM, whereas those in Group C are willing to pay 28.6 percent more for HIPM compared with LPM (Table 5).

3.4. Regression Analysis

Exploratory data analysis (including OLS regressions not presented here) shows that socioeconomic variables such as household size, ownership of assets other than land, area under pearl millet cultivation, sources of pearl millet consumption (own production, rural and urban markets), and their percentage contribution to overall consumption, have no significant effect on participants' WTP. It is possible that 1 kg of pearl millet is too little, at the margin, to be affected greatly by variation in these characteristics.

On the other hand, since we have two bids per participant (one each for LPM and HIPM), we exploit the panel structure of the data. Individual heterogeneity is a significant source of variation in WTP. Thus, we estimate models described by Equation (1) below:

$$WTP_{ij} = x_{ij}^{'}\beta + \mu_i + \varepsilon_{ij} \qquad (1)$$

giving participant *i*'s WTP for pearl millet variety *j* as a function of variables x_{ij}, and error terms, including a random individual effect μ_i (Durbin-Wu-Hausman tests do not reject the random-effects models reported in Table 8). The relatively parsimonious choice of regressors is informed by the exploratory analysis mentioned above.

Table 7 presents the estimates for three different random-effects models, which allow us to estimate the effect of nutrition information, and the effect of the type of brand and certifying authority (international versus state-level) more efficiently. Model 1 (Table 7, column 2) controls for the effect of the variety being HIPM, the presence of information, and the type of certification/branding (Information and state-level branding and certification versus Information and International branding and certification), and their interactions. In addition, we include "relative trust" (the participant's ratio of trust in international versus national certification authorities) and its interactions with HIPM and national and international treatments. Interactions of "relative trust" do not significantly differ by sex and are dropped.

Model 2 (Table 7, column 3) controls for districts, in addition to the variables mentioned for Model 1. In addition to this, Model 3 explores the effect of prior awareness of iron-rich foods. We have also estimated, but do not report here, models that include interactions of the district dummies with other variables. While the interactions are insignificant, the number of variables is more than twice the numbers of Models 2 and 3, As a result, these larger models do relatively poorly in terms of goodness-of-fit measures, such as Akaike Information Criterion (AIC) scores. Moreover, interacting district with treatments and participant's sex results in cell sizes of less than 20; this does not allow us to place any confidence in the corresponding estimates.

The principal a priori effects of the experiment are the changes in WTP for HIPM resulting from the nutrition information and brand treatments. The magnitude and significance of these are virtually the same across the three models in Table 7, corroborating the randomized allocation to the treatments. Models 2 and 3 reveal that across treatments, participants from Nashik and Solapur were willing to pay more for pearl millet, compared with their counterparts in Ahmednagar. Model 3 also shows that apart from Group C (nutrition information and state-level brand), prior knowledge of iron-rich foods was not correlated with WTP for HIPM. For Group C, the marginal effect of this knowledge is positive for men, but not for women. However, the number of men and women in Group C with knowledge of iron-rich foods is about 10 each, so we do not attach much significance to these estimates. Instead, the discussion that follows uses the more parsimonious and better-fitting (in terms of the AIC) Model 2, in which interacted dummies do not result in such small cell sizes.

Table 8 presents WTP differences across treatments, sex, and pearl millet varieties, estimated using Model 2. In the absence of nutrition information, women were willing to pay more for LPM than were men, but the difference was *not* significant for HIPM (Table 8, rows 1 and 2). Comparing WTP for HIPM across treatments and sex, we find that neither men nor women have significantly higher WTP in the presence of information *and* the state-level brand and certification authority, relative to the no information treatment (Table 8, rows 6 and 9). However, participants of either sex are willing to pay significantly more for the information and international brand and certification authority treatment, compared with both the no information and the information and state-level brand and certification authority treatments (Table 8, rows 5.1 and 8.1). On the other hand, in the information and brand/certification authority treatments, women are willing to pay significantly more for both information treatments compared with men (rows 11 and 12).

WTP for HIPM differs from WTP for LPM across treatments. For male participants, the HIPM–LPM premium difference for information and state-level brand and certification authority over no information is Rs 2.11, and the premium difference for the information and international brand and certification authority over no information Rs 2.36. For female participants, the corresponding premium differences are Rs. 3.15 and 3.87.

Relative trust (the ratio of the international and national/state-level certification agency trust scores) has a positive and significant impact on consumer WTP for HIPM in Group B (information and international brand and certification treatment). However, its impact on WTP for HIPM (information and state-level brand and certification treatment) is insignificant in Group C. That is, a higher prior "relative trust" in international certification authorities translates into a higher WTP for HIPM in the information and international brand treatment. For both men and women, therefore, WTP for international brand and delivery evaluated at the sample mean level of relative trust is higher by almost Rs. 0.80. Thus, WTP for international brand relative to national brand is higher, but **not significantly so**, for either sex, at a relative trust score = 0; but it is **significantly higher** in the case of women, at the **mean** level for relative trust.

It is interesting that higher levels of trust in international agencies (relative to state agencies) have a positive impact on WTP for HIPM with an international brand and certification. A large fraction of participants in our sample was unaware of relevant international authorities, assigning neutral and lower trust scores to them than to national authorities. However, awareness and trust in international authorities are correlated with higher WTP for HIPM in the information and international brand and certification authority treatment. This suggests that a nutrition information campaign that also leads to increased awareness of a suitable international brand and certifying authority to add fillip to consumers' WTP for HIPM.

4. Conclusions and Implications

In this paper we used the Becker-DeGroot-Marschak (BDM) mechanism and sensory evaluation methods to shed light on consumer acceptance of biofortified high-iron pearl millet (HIPM) in India. Willingness to pay (WTP) and sensory evaluation data were collected for two different pearl millet varieties (HIPM and a control, local pearl millet [LPM]) from 452 rural consumers Maharashtra, one of the major pearl millet-growing and consuming states in the country.

Unlike biofortification with provitamin A, biofortification with minerals, such as iron and zinc, does not change the color or the appearance of the biofortified crop. Therefore, in this study we investigated the impact of nutrition information, branding and certification, as well as the nature of the brand and of the certifying authority (state-level versus international) on consumer acceptance of HIPM.

The results reveal that even in the absence of nutrition information, relative to the local variety, consumers assign a small but significant premium to the HIPM variety evaluated. This is consistent with consumers' more favorable evaluation of the sensory characteristics of the high-iron variety. Nutrition information on the health benefits of HIPM was found to increase this premium substantially. The results show that, while women at the mean level of relative trust significantly prefer international to state-level branding and certification, the difference is positive but statistically insignificant for men. Since women are the main decision makers in feeding their families, certification, branding, and promotion of HIPM varieties through international agencies could result in higher adoption and consumption rates.

Tables and Figures

Table 1. Participant- and household-level socioeconomic characteristics, by treatment group

Key participant and household characteristics	**Group A**	**Group B**	**Group C**
	N = 229	N = 110	N = 113
	Mean (standard deviation)		
Participant age in years	40.52 (12.26)	39.85 (12.58)	38.63 (12.12)
Participant education in years	8.66 (4.95)	9.02 (5.12)	8.05 (5.66)
Household size*	6.35 (4.04)	5.96 (3.34)	5.48 (3.07)
Number of vulnerable people in the household	2.56 (1.96)	2.65 (2.03)	2.38 (1.70)
Area of land owned by the household (ha)	3.52 (4.60)	3.20 (4.53)	3.00 (5.00)
Relative trust	0.90 (0.50)	1.03 (0.64)	1.03 (0.75)
	Percentage		
Participant sex (woman = 1; 0 otherwise)***	37.12	40	57.52
Participant has heard of iron-rich foods = 1; 0 otherwise	26	20	20
Participant has heard of anemia = 1; 0 otherwise	20	21	20
Household currently	83.41	76.99	80.91

Key participant and household characteristics	Group A	Group B	Group C
	N = 229	N = 110	N = 113
	Mean (standard deviation)		
has pearl millet at home* = 1; 0 otherwise			
Household is producing pearl millet = 1; 0 otherwise	49.78	49.09	44.25

*, ***Pairwise, one-sided t-tests and Pearson's Chi-squared tests reveal statistically significant differences in participant and household characteristics across treatment arms at 10 percent and 1 percent significance level, respectively.

Table 2. Mean sensory characteristics and comparison of grain and *bhakri* from HIPM and LPM, by treatment group

Treatment group	**Variety**	Grain color	Grain size	*Bhakri* color	*Bhakri* taste	*Bhakri* layers	*Bhakri* ease of breaking
A	HIPM	4.43 (0.85)	4.69 (0.63)	4.39 (0.94)	4.16 (1.13)	4.21 (1.17)	4.49 (0.95)
	LPM	4.22 (1.06)	3.92 (1.16)	4.07 (1.08)	4.11 (1.16)	4.18 (1.11)	4.24 (1.03)
	HIPM vs. LPM	*2.34****	*8.84****	*3.46****	*0.46*	*0.24*	*2.78****
B	HIPM	4.76 (0.52)	4.85 (0.43)	4.68 (0.79)	4.73 (0.52)	4.76 (0.61)	4.73 (0.57)
	LPM	4.2 (1.11)	3.55 (1.24)	3.62 (1.29)	3.65 (1.16)	3.60 (1.29)	3.79 (1.24)
	HIPM vs. LPM	*4.8****	*11.92****	*7.3****	*8.76****	*8.36****	*6.28****
C	HIPM	4.74 (0.62)	4.84 (0.56)	4.65 (0.78)	4.78 (0.52)	4.63 (0.65)	4.76 (0.52)
	LPM	4.15 (1.05)	3.53 (1.15)	3.68 (1.24)	3.50 (1.23)	3.62 (1.29)	3.88 (1.29)
	HIPM vs. LPM	*5.18****	*10.88****	*7.02****	*9.09****	*7.08****	*6.71****

** Significant at 5 percent (one-sided test).

*** Significant at 1 percent.

Table 3. Comparison of mean sensory characteristics of grain and *bhakri* from HIPM and LPM across treatments

Variety	**Treatment group**	Grain color	Grain size	*Bhakri* color	*Bhakri* taste	*Bhakri* layers	*Bhakri* breaking
HIPM	B vs. A	3.81***	2.27**	2.72***	5.01***	4.58***	2.48***
	B vs. C	0.26	0.07	0.31	–0.6	1.47	–0.34
	C vs. A	3.51***	2.09**	2.45***	5.34***	3.4***	2.8***
LPM	B vs. A	–0.15	–4.11***	–3.31***	–3.32***	–4.17***	–3.47***
	B vs. C	0.34	–1.07	–0.34	0.92	–0.1	–0.56
	C vs. A	–0.56	–2.95***	–2.95***	–4.33***	–4.1***	–2.72***

** Significant at 5 percent (one-sided test).

*** Significant at 1 percent.

Table 4. Mean WTP for 1 kg grain, by treatment group and variety

Variety	**Group A**	**Group B**	**Group C**
	N = 229	N = 110	N = 113
	Mean (standard deviation)		
HIPM	13.63 (4.29)	15.34 (4.95)	14.60 (4.63)
LPM	12.80 (4.69)	11.59 (3.90)	11.35 (3.77)

Table 5. Comparison of mean WTP for 1 kg of grain for each variety <u>within</u> treatment groups

Variety	**Group A**	**Group B**	**Group C**
	t-statistics difference in means		
HIPM vs. LPM	6.5% (4.22)***	32.35% (8.39)***	28.63% (7.04)***

*** Significant at 1 percent (one-sided test).

Table 6. Comparison of mean WTP for 1 kg for each variety across treatment groups

Treatment group	HIPM	LPM
	t-statistics difference in means	
B vs. A	12% (3.25)***	–9% (–2.34)***
B vs. C	5% (1.15)	2% (0.48)
C vs. A	7% (1.91)**	–11% (–2.87)***

** Significant at 5 percent (one-sided test).

*** Significant at 1 percent.

Table 7. Determinants of WTP for 1 kg of pearl millet: random effects models

Variable	Model 1: Sex, trust estimate (t-statistic)	Model 2: Sex, trust, district (main effects)	Model 3: Model 2 variables plus "heard of iron-rich foods" variable
Constant	12.30 (24.50)***	11.70 (20.55)***	11.46 (19.78)***
HIPM	1.21 (3.57)***	1.21 (3.57)***	1.12 (3.26)***
Nashik	________	1.01 (2.13)**	0.90 (1.78)*
Solapur	________	0.85 (1.73)*	1.00 (2.03)**
Sex (woman = 1; 0 otherwise)	1.61 (2.65)***	1.48 (2.44)**	1.34 (2.21)**
Heard of iron-rich foods (ironHeard)	________	________	0.55 (1.09)
Information and state-level branding and certification	–1.12 (–1.48)	–1.31 (–1.73)*	–1.36 (–1.80)*
Information and international branding and certification	–1.05 (–1.55)	–1.01 (–1.50)	–1.04 (–1.55)
Relative trust	–0.22 (–0.47)	-0.18 (-0.40)	-0.14 (-0.30)
HIPM * sex	–1.06 (–2.58)***	–1.06 (–2.58)***	–0.96 (–2.3)**
HIPM * ironHeard	________	_________	–0.26 (–0.49)
HIPM * Information and state-level branding	2.11 (4.16)***	2.11 (4.16)***	2.17 (4.24)***
HIPM * information and international branding	2.36 (5.18)***	2.36 (5.18)***	2.42 (5.27)***
Relative trust * HIPM	–0.14 (–0.45)	–0.14 (–0.45)	–0.07 (–0.21)
Sex * ironHeard	________	_________	0.86 (1.15)
Sex * information and state-level	–1.10 (–1.05)	–0.74 (–0.70)	–0.59 (–0.56)

branding			
Sex* information and international branding	–0.39 (–0.37)	–0.35 (–0.33)	–0.17(–0.16)
ironHeard * information and state-level branding	________	_________	0.59 (0.54)
ironHeard * Information and international branding	________	_________	0.68 (0.63)
Relative trust * information and state-level branding	0.23 (0.50)	0.24 (0.52)	0.12 (0.24)
Relative trust * information and international branding	0.11 (0.23)	0.18 (0.39)	0.07 (0.14)
HIPM * sex * ironHeard	________	_________	0.26 (0.35)
HIPM * Sex * information and state-level branding	1.04 (1.47)	1.04 (1.47)	0.83 (1.16)
HIPM * sex * information and international branding	1.50 (2.10)**	1.50 (2.10)**	1.43 (2.00)**
HIPM * ironHeard * information and state-level branding	________	________	2.51 (2.35)**
HIPM * ironHeard * information and international branding	________	________	0.80 (0.79)
Relative trust * HIPM * * information and state-level branding	–0.09 (–0.29)	–0.09 (–0.29)	–0.27 (–0.80)
Relative trust * HIPM * information and international branding	0.61 (1.96)**	0.61 (1.96)**	0.54 (1.60)
HIPM * sex * ironHeard * information and state-level branding	________	________	–2.53 (–1.82)*
HIPM * sex * ironHeard * information and international branding	________	________	–0.87 (–0.61)
Individual variance	14.98	14.90	14.64
Idiosyncratic variance	4.41	4.40	4.42
rho (individual variance as fraction of total)	0.64	0.64	0.64
Hausman chi-squared statistic	0.0 (dof = 9)	0.0 (dof = 9)	4.86 (dof = 15)
Adjusted R-squared	0.28	0.28	0.28
AIC	7514	7515	7530
Sample Size = 452 x 2			

* Significant at 10 percent.

** Significant at 5 percent.

*** Significant at 1 percent.

Table 8: WTP differences across varieties, treatments, and sex, evaluated for Model 2 of Table 8.

WTP differences		Null hypothesis: terms refer to corresponding coefficients	Test statistic
1. LPM (female – male): Group A	1.48**	Sex = 0	t = 2.44**
2. HIPM (female – male): Group A	0.42	Sex + HIPM * sex = 0	chi-square = 0.50
3. LPM (Group B – Group A)	-1.01	InfoInternational = 0	t = –1.50
4. LPM (Group C – Group A)	-1.31*	InfoState = 0	t = –1.73*
5.1. HIPM (Group B – Group A): male, relative trust = 0	1.35*	InfoInternational + HIPM * InfoInternational = 0	chi-square = 3.26*
5.2. HIPM (Group B – Group A): male, at mean relative trust = 1	2.14**	InfoInternational + HIPM * InfoInternational + relative trust * InfoInternational + relative trust * HIPM * InfoInternational = 0	chi-square = 4.83**
6. HIPM (Group C – Group A): male	0.80	InfoState + HIPM * InfoState = 0	chi-square = 1.21
7.1. HIPM (Group B – Group C): male, relative trust = 0	0.55	InfoInternational – InfoState + HIPM * (InfoInternational – InfoState) = 0	chi-square = 0.41
7.2. HIPM (Group B – Group C): male, at mean relative trust	1.04	InfoInternational – InfoState + HIPM * (InfoInternational – InfoState) + relative trust * (InfoInternational – InfoState) + relative trust * HIPM * (InfoInternational – InfoState) = 0	chi-square = 2.06
8.1. HIPM (Group B – Group A): female, relative trust = 0	2.50***	InfoInternational + HIPM * InfoInternational + sex * Infointernational + HIPM * sex * InfoInternational = 0	chi-square = 8.16***
8.2. HIPM (Group B – Group A): female, at mean relative trust	3.29***	InfoInternational + HIPM * InfoInternational + sex * Infointernational + HIPM * sex * InfoInternational + relative trust * InfoInternational + relative trust * HIPM * InfoInternational = 0	chi-square = 9.79***
9. HIPM (Group C – Group A): female	1.10	InfoState + HIPM * InfoState + sex * InfoState + HIPM * sex * InfoState = 0	chi-square = 2.08
10.1. HIPM (Group B – Group C): female, relative trust = 0	1.40	(InfoInternational – InfoState) * (1 + HIPM + sex + HIPM * sex) = 0	chi-square = 2.15
10.2. HIPM (Group B – Group C): female, at mean relative trust	2.29*	(InfoInternational – InfoState) * (1 + HIPM + sex + HIPM * sex + relative trust + relative trust * HIPM) = 0	chi-square = 3.53*
11. HIPM (female – male): Group B	2.68**	Sex + sex * InfoInternational + HIPM * sex * InfoInternational = 0	chi-square = 6.12**
12. HIPM (female – male): Group C	1.86*	Sex + sex * InfoState + HIPM * sex * InfoState = 0	chi-square = 3.21*

Notes: (i) *, **, ***: Refer to significance at 10, 5, and 1 percent levels, respectively.

(ii) Groups A, B, and C were treatments, respectively, with no nutrition information, and nutrition information with international and national brands and certification. Sex = 1 for women, 0 for men. InfoState and InfoInternational refer to the treatments for Groups B and C, respectively.

(iii) WTP comparisons involving Group B versus another group are conditioned on (a) relative trust = 0, and (b) relative trust = 1 (i.e., the mean for the trust variable in Groups B and C). Conditioning on relative trust = 0 is for convenience; the minimum relative trust score in the data equals 0.2.

(iv) Sex differences are not significant in 3 and 4.

Figure 1. International (left) and state-level (right) brands used in the experiment

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Appendix. Infomercial Text

Characters: Sumi, 25-year-old wife and mother; son-in-law, 30 years old; Bayaja, Sumi's mother, 45 years old; Tayadi, Sumi's sister, 17 years old; and Bhau, Sumi's father, 50 years old.

Plot: Sumi and her husband are visiting Sumi's parents. It is dinner time.

Scene 1 (Sumi and her husband come to her parents' house)

Son-in-law Bhau, O Bhau.

Bhau Welcome, welcome (son-in-law)! Bayaja, did you hear? Our son-in-law has come. Come in, come in.

Son-in-law Let me touch your feet.

Bhau May you have a long life.

Sumi Where is Mother?

Bhau She is in (the kitchen).

Scene 2 (Sumo and Bayaja are in the kitchen. Sumi is cleaning vegetables, Bayaja is kneading the dough for *bhakri*, a pan is on the stove.)

Bayaja It's so good Sumi, that both of you could come. Now you should stay with us for three or four days.

Sumi How is it possible to stay for three or four days? I have to go back for Manya. He is hardly four years old. He can't stay without me.

Tayadi (Comes to the door) Sister, when did you come? Mother, I am hungry.

Bayaja Let me make all the *bhakri* and then all of us will eat together.

Sumi Wow, you are making *bhakri*! My husband loves *bhakri*!

Bayaja Yes, *bhakri* is delicious. And this is our own pearl millet, grown on our farm.

Tayadi And Sister, it's not only from our farm; it also contains iron.

Sumi Tayadi, pearl millet always contains iron, so what's special about this one?

Tayadi This pearl millet contains 30 percent more iron than the normal varieties.

Scene 3 (Bhau and son-in-law having dinner)

Bhau I tell you (son-in-law), this variety of pearl millet is really special. It's cultivated the usual way, but the grain contains much more iron.

Son-in-law Which variety is it, you said?

Bhau HarvestPlus [*Samarth*] pearl millet. It's too good! It has much more iron than the usual varieties.

Son-in-law Bhau, that's incredible.

Bhau Of course! Renowned researchers have developed this variety.

Son-in-law Bhau, I had heard that you get the iron you need for your health from meat, fish, and chicken, but if our daily pearl millet bread can also give some of the iron, that's great news.

Bhau What are you saying? Do meat and fish give iron?

Son-in-law Yes they do, but they are so expensive….

Bhau … and are not affordable. Then our HarvestPlus [*Samarth*] *bhakri* is very good because it is an additional source of iron and is also affordable.

<u>Scene 4</u> (All sitting in the garden)

Sumi It was a delicious meal, Mother! Now even I will make *bhakri* of this pearl millet to give to Manya. Children in their growing years need iron.

Bayaja Hey girls, you two have been talking about iron for a long time now. But I don't understand why does our body need iron?

Tayadi Mother, iron gives strength to the body so we don't get tired easily. Our science book explains it all.

Sumi Tayadi, not only that, iron also keeps anemia at bay.

Tayadi Anemia means lack of blood, doesn't it sister? But what happens if one has anemia?

Sumi We get tired very often, we don't feel like working. Iron helps overcome lack of blood. So Mother, all women, especially pregnant women, must eat this high-iron pearl millet bread.

Bayaja Sumi, so you mean to say pearl millet bread from the HarvestPlus [*Samarth*] variety can give you more iron? We must give it to Pandba's daughter Akki. She is pregnant, you know!

Sumi Not only that, adolescent girls, young children, even men who work hard in the field must eat pearl millet bread for added strength and good health.

Tayadi Mother, but not just any pearl millet bread.

Bayaja I know, I know, what is the name? *Bhakri* from HarvestPlus [*Samarth*] pearl millet, isn't it?

Bhau Bayaja, now you spoke like a wise person. Always remember HarvestPlus [*Samarnth*] pearl millet means pearl millet with more iron.

Bayaja Key to good health!

(All laugh)

End credits (also with voiceover)

HarvestPlus Pearl Millet – Certified by International Health Authorities (Group B infomercial)

Or

Samarth Pearl Millet – Certified by Maharashtrian Health Authorities (Group C infomercial)