The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/2044-0839.htm

Are non-farming consumers willing to pay "a good market price" for iron-biofortified finger millet? Evidence from experimental auctions in Karnataka, India

Received 6 November 2019
Revised 28 January 2020
Accepted 31 January 2020

Claudia Meier
Research Institute of Organic Agriculture, Frick, Switzerland
Nadja El Benni
Agroscope, Ettenhausen, Switzerland
Srinivasaiah Sakamma
University of Agricultural Sciences, Bangalore, India
Simon Moakes, Christian Grovermann, Sylvain Quiédeville,
Hanna Stolz and Matthias Stolze
Research Institute of Organic Agriculture, Frick, Switzerland, and
K. Basegowda Umesh
University of Agricultural Sciences, Bangalore, India

Abstract

Purpose – Biofortification of staple crops is a promising strategy to alleviate micronutrient deficiencies in rural populations of the developing world. The possibility to sell biofortified crops at "a good market price" plays a vital role for the acceptance by smallholder farmers. This study is therefore focused on non-farming consumers' willingness to pay (WTP) for biofortified crops.

Design/methodology/approach – Specifically, we elicited non-farming consumers' WTP a premium for the improved iron content (+30% iron) in a 1kg finger millet bag using a 2nd price Vickrey auction with six auction rounds and one health- and one process-related information treatment. Due to multiple bids per subject, premiums were analyzed using a linear mixed-effects model, controlling for market feedback and auction round.

Findings – Despite more than half of the respondents being skeptical toward new crop varieties, the acceptance rate was very high (98% with a WTP above zero). The average premium amounted to 27% and could be significantly increased with the provision of health-related information. In contrast, information about the breeding method was ineffective. The WTP was significantly higher for higher income and lower for higher age, education and skepticism toward new crop varieties and increased with increasing rounds.

Research limitations/implications – Our results suggest that non-farming consumers are willing to pay "a good market price" for iron-biofortified finger millet. Our analysis also confirms the importance of health-related information for raising consumers' WTP. This information supports the further development and introduction of biofortified crops to alleviate micronutrient malnutrition.

The authors gratefully acknowledge the financial support of the Indo-Swiss Collaboration in Biotechnology (ISCB). The authors also thank Lukas Meier from ETH Zurich and Riccardo Vecchio from the University of Naples for their valuable comments and suggestions.

Journal of Agribusiness in Developing and Emerging Economies

2044-0839
DOI 10.1108/JADEE-11-2019-0190

Originality/value – This study adds to the still limited literature on consumers' WTP for iron-biofortified crops in India, focusing on non-farming consumers to assess the price such crops can achieve on the market.

Keywords Experimental auctions, Willingness-to-pay, India, Iron-biofortification, Finger millet, Health benefits, Modern breeding techniques

Paper type Research paper

1. Introduction

A promising strategy to tackle micronutrient malnutrition in poor, rural regions of the developing world is biofortification, i.e. the development of staple crops with an enhanced micronutrient content, using conventional plant breeding or genetic engineering (Bouis *et al.*, 2011; Das *et al.*, 2018; Meenakshi *et al.*, 2010). It is expected to have a large impact for the rural poor who may not have access to other nutrition interventions such as fortification or dietary diversification and to be a valuable complement to direct nutrition interventions, like supplementation (Finkelstein *et al.*, 2017; Stein *et al.*, 2008). The HarvestPlus programme of the International Food Policy Research Institute (IFPRI) initiated the process of biofortification in 2003 and is now considered the global leader in biofortification using conventional breeding methods. By the end of 2018, it had developed and released over 300 varieties of 11 staple crops in over 30 countries of the global South. However, to make a significant contribution to mitigating micronutrient malnutrition, further investments in biofortification are required, by HarvestPlus and many other partners (Herrington *et al.*, 2019).

In India, investments in the biofortification of millets, including minor millets, should be a top priority (Asare-Marfo *et al.*, 2013). In comparison to major cereals, such as wheat, rice and maize, millets are not only more resilient to harsh agro-climatic conditions but also have a better nutritious profile (Bala Ravi *et al.*, 2010). Furthermore, they have played and continue to play an important role in India's agriculture and diets (Padulosi *et al.*, 2015). Some biofortified millet varieties have already been released and others are in the making. Under the leadership of HarvestPlus, nine iron-biofortified pearl millet varieties have been approved for delivery to farmers. In addition, the Ragi (finger millet) network, one of the research networks within the Indo-Swiss Collaboration in Biotechnology (ISCB), is paving the way for the development and introduction of nutritionally superior (with a particular focus on iron and zinc), high yielding and climate resilient finger millet varieties, using new breeding methods not involving genetic modification (GM) (SDC, 2016).

The success of biofortification as a nutrition intervention requires the acceptance of biofortified crops by smallholder farmers as producers, consumers and marketers of the crop (Mogendi *et al.*, 2016b; Peters *et al.*, 2013). Since the possibility to sell biofortified crops "at a good market price" plays a vital role for smallholder farmers' acceptance, given they produce for market sales, (Asare-Marfo *et al.*, 2010; Birol *et al.*, 2011, 2015a) the premium non-farming consumers would be willing to pay on the market is also very important.

There is a growing literature on consumers' Willingness to pay (WTP) for biofortified staple crops in developing countries mainly focusing on consumers' valuation of nutritional traits and the related health benefits as well as sensory qualities such as taste, color and cooking properties (Birol *et al.*, 2015b; Talsma *et al.*, 2017). As some biofortified crops' are developed using biotechnology, such as GM, consumers' process-related risk and benefit perceptions also play an important role (De Steur *et al.*, 2017). Even though farming and non-farming consumers' varietal adoption behavior has been shown to be different, as farmers not only trade-off a crop's consumption but also production traits (De Steur *et al.*, 2010; Murekezi *et al.*, 2017), studies usually do not differentiate between the two. Due to the long-standing involvement of HarvestPlus in Africa and focus on conventional breeding methods, the available literature is dominated by studies on consumers in Africa and their WTP for conventionally bred biofortified staple crops, particularly provitamin A biofortified sweet potato, maize or cassava (Chowdhury *et al.*, 2011; De Groote *et al.*, 2011; Oparinde *et al.*, 2016).

To measure consumers' WTP, most studies have applied experimental auctions (Birol *et al.*, 2015b; Talsma *et al.*, 2017).

According to the evidence base available to date, consumers from developing countries are willing to pay more for biofortified foods or at least as much as for conventional ones (Banerji *et al.*, 2016; Oparinde *et al.*, 2015; Pérez *et al.*, 2018). Informing consumers about the health benefits these foods provide helps to further raise consumers' WTP and is key if biofortification leads to adverse changes in color, taste or cooking properties (Banerji *et al.*, 2013; De Groote and Kimenju, 2008; Garcia-Casal *et al.*, 2017; Oparinde *et al.*, 2016; Talsma *et al.*, 2017) or was implemented following a controversial technical process, like GM (De Steur *et al.*, 2017). Evidence on the influence of socio-demographic characteristics is less consistent and seems to be very study specific (Mogendi *et al.*, 2016a). Whereas age, gender, income and education are considered the most important influencing factors, the direction of their effects seems to depend to a large extent on the crop-micronutrient combination studied, the information treatments used and the study's target group. To generate recommendations for effective marketing strategies, it is therefore recommended to study each crop-country-micronutrient combination individually by target group (Birol *et al.*, 2015b; De Steur *et al.*, 2010).

The research presented in this paper is part of ISCB and aimed at testing whether an iron-biofortified finger millet (IBFM) variety could be sold "at a good market price" to non-farming consumers in Karnataka, a major finger millet producing and consuming state in India (Divya, 2011; Sakamma *et al.*, 2018). In contrast to iron-biofortified pearl millet developed under the leadership of HarvestPlus using conventional breeding, IBFM is being developed using new breeding techniques, without the application of GM. In comparison to local finger millet (LFM), IBFM is expected to have at least 30% higher bioavailability of iron (Stein *et al.*, 2008; Velu *et al.*, 2007) and also remains the same in terms of sensory qualities, such as color, taste or cooking properties (Das *et al.*, 2018). Consequently, we investigated consumers' WTP for the increased iron content without and with additional information on the health benefits of iron (health-related information) as well as the use of modern breeding techniques not involving GM (process-related information).

This study aimed to answer the following research questions:

(1) Are non-farming consumers willing to pay a premium for iron-biofortified finger millet?

(2) How is non-farming consumers' valuation affected by positive health-related information?

(3) How is non-farming consumers' valuation affected by process-related information indicating the non-GM nature of the crop?

(4) What role do prior health-related knowledge, prior skepticism toward newly bred varieties and socio demographics play in non-farming consumers' valuation?

The next section outlines the methodology applied, followed by the presentation of the empirical results. The final section provides a discussion, including key limitations and recommendations for future research and a conclusion.

2. Material and methods

To investigate non-farming consumers' WTP for IBFM we used an experimental auction approach. Experimental auctions are increasingly popular for estimating consumers' WTP for new food products because they are considered to be incentive compatible and therefore demand revealing (Lusk *et al.*, 2007; Vecchio and Annunziata, 2018). An experimental auction creates a non-hypothetical value elicitation environment with real products and real monetary consequences in which a participant's best strategy is to reveal his/her true private preferences (Lusk and Shogren, 2007).

2.1 Choice of auction mechanism

Over the years, different types of experimental auctions have been developed and validated (Lusk *et al.*, 2007). The two types most commonly applied are BDM (short for Becker–DeGroot–Marschak) and nth price auctions, whereas n stands for the number of auction winners, which can range from 2 to a maximum of half the number of participants (Lusk and Shogren, 2007; Vecchio and Annunziata, 2018). Whereas an nth price auction is administered in a group of multiple participants which form the market-like environment, a BDM auction is administered individually. Whilst group auctions are ideal for environments with a high population density where central-location testing is possible, individual auctions are more suitable for environments with a low population density where home-use testing is preferred (De Steur *et al.*, 2016). For this study we opted for an nth price auction due to the focus on non-farming consumers which typically live in more densely populated areas than farming consumers.

An nth price auction uses a simultaneous sealed bidding procedure to identify the n-1 participants with the highest WTP ("the winners"), who then have to purchase the auctioned good at the price of the nth highest bidder (Lusk and Shogren, 2007). Under these circumstances, participants' best strategy is to bid their own maximum WTP, also referred to as "true" WTP because by underbidding, they risk forgoing a good deal and by overbidding they risk paying too much. In theory, this holds for any nth price auction. However, practice has shown that participants lose interest in bidding if they consider it highly unlikely they can win (which is assumed to be the case if n/#participants < 0.5). Therefore, Lusk and Shogren (2007) recommend that n should be set equal to half the participants in an experimental session. However, even though we had twenty participants per auction session in this study, we followed De Steur *et al.* (2012) and applied the 2nd ($n = 2$) price Vickrey auction mechanism (Vickrey, 1961). Compared to auctions with $n > 2$ or where n is randomly defined between 2 and n/#participants (Shogren *et al.*, 2001), it has the advantage that participants can more easily understand its procedures (Lusk, 2003; Lusk and Shogren, 2007). Regarding the rural context with a lack in technical facilities and participants with little experience in consumer experiments, simplicity of implementation was considered highly relevant for the validity of the results.

2.2 Auction design

We conducted a total of six experimental sessions with 20 participants each. Two parallel sessions were undertaken by two previously trained teams at three different times during the same day. To ensure that auction procedures did not differ between auction sessions, the teams closely followed the detailed auction instructions [1]. To avoid interaction among participants, each participant sat at an individual table.

As illustrated in Figure 1, each experimental session followed a within-subject design (West *et al.*, 2004) with a total of six auction rounds. The repetition of rounds is a common practice in experimental auction research. It gives participants the opportunity to incorporate market feedback, which is provided after every round, as well as learn their optimal bidding strategy (List and Shogren, 1999). Furthermore, it allows to measure the effect of additional information that is provided in-between rounds in the form of an 'information shock' (De Steur *et al.*, 2012; Jaeger and Harker, 2005; Lusk *et al.*, 2004b; Roosen *et al.*, 1998). In each auction, we provided two information treatments: Information Treatment 1 after Round 2 informed participants of the health benefits of iron (health-related information), and Information Treatment 2 after Round 4, informed participants that IBFM had been developed using modern breeding techniques not involving GM (process-related information). Due to time and budget constraints, there was no control group and for the sake of simplicity, we chose not to randomize treatments. In a repeated measures design, the absence of a control group can lead to the confounding of the treatment effect by a time (or learning) effect. To solve this problem, the variable Round was controlled for when the treatment effect was analyzed (see section 2.5). The non-randomization of multiple treatments can lead to the confounding of treatment effects by an order effect, meaning that the effect of the second treatment might be different from the effect of the first one, only because it always came second. This effect could not be controlled for in the analysis, but was taken into account when interpreting the results.

With multiple rounds there are multiple winning opportunities. The prospect of winning multiple times leads to demand reduction and a consequent change in bidding behavior. Therefore, it is important to introduce a simple rule at the beginning of an experimental session that ensures that there can be only one winner (Shogren *et al.*, 1994a). In this study we followed the commonly used single binding approach (see De Steur *et al.* (2012) for a recent example of an application). We informed participants at the beginning of the experiment that once the experiment was complete we would randomly select one of the six rounds as binding and announce the highest bidder of that round as the one and only winner.

To collect information regarding the socio-economic characteristics, prior knowledge and attitudes of the participants we used an auction survey. To avoid anticipating any information that could unintendedly affect their bidding behavior, we followed the approach of De Steur *et al.* (2012) and split the survey into three subsections. The first section was administered before Round 1 (mainly socio-economic information), the second before Round 3 (questions on health benefits of iron) and the third before Round 5 (questions on development of new crop varieties).

In experimental auctions where two or more products are sold, the experimenter can choose between full bidding (participants simultaneously bid for all products) and endowment approach (participants are endowed with the 'inferior' good and bid to upgrade to the novel good) (Lusk and Shogren, 2007). The latter is recommended if one of the products is clearly inferior to the others with respect to the characteristic to be valued and if that product has close substitutes on the market (Hanemann, 2003; Shogren *et al.*, 1994b). As this is the case for LFM, the endowment approach was adopted for this study.

2.3 Auction procedures

Each experimental session lasted about 90 min and consisted of the following six steps:

(1) *Welcome to the study site* (general introduction, distribution of participant ID's)

(2) Random auction room allocation

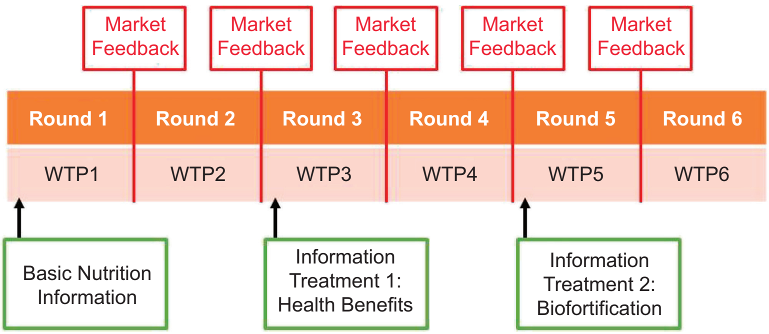


Figure 1. Within-subject design with six auction rounds, two information treatments and five market feedbacks

(3) *Introduction to the experiment* (study purpose, monetary compensation upon successful completion of the experiment of Rs. 1,500 (US$ 20.55), confidentiality of answers, auction rules (e.g. no communication), first part of auction survey)

(4) *Training* (role play with numerical example, quiz, trial chocolate auction with four auction rounds and one information treatment)

(5) *Finger millet auction* (including second and third part of the auction survey)

(6) Debriefing

The Training (step 4) is an integral part of an experimental auction. It is undertaken to ensure the participants are familiar with the procedure of the auction and show them why it is in their best interest to bid what the product is worth to them and not more or less than that.

2.3.1 Finger millet auction and debriefing. The finger millet auction (step 5) started with each participant receiving six bidding slips and 1kg of LFM grains (the endowment) in transparent packaging to avoid brand bias. Participants were informed that this product was worth Rs. 35 (reference price). No auction budget was provided. Next, participants were shown the product to be auctioned, 1kg of IBFM, also in transparent packaging. As the iron content of a crop is an invisible consumption trait (Birol *et al.*, 2015b), participants had to be provided with the following basic nutrition information before the start of the actual bidding process:

Basic nutrition information:

> "Please note that your ragi product and this [indicate] ragi product are exactly the same in terms of appearance, taste and cooking properties, except that this [indicate] ragi product contains about 30% more iron. If you consume about 170g of this [indicate] high-iron ragi product per day, you can cover your daily requirement in iron. Of your ragi product, you would have to consume about 230g to cover your daily requirement in iron."

The auction started with the first two rounds. In each round, participants were asked to simultaneously state their maximum WTP to exchange their LFM grains with the IBFM grains. Every time bidding was completed, market feedback was provided, i.e. the bidding slips were collected, ranked and the ID of the highest bidder as well as the 2nd highest bid were posted on a board for all participants to see. At the end of Round 2, the second part of the auction survey was distributed and filled in by the participants. Next participants were given the first information treatment about the health benefits of iron:

Information Treatment 1: health-related information:

> "Iron is a very important micronutrient for the human body. It gives strength to our body, so that we do no't get tired easily. Iron is important for the development of red blood cells and strengthens the human immune system. If the intake of iron is not sufficient, our body does not develop enough red blood cells and we get tired very often. It feels like we do no't get enough oxygen. Growing children or pregnant women have greater iron requirements. For them, it is therefore particularly important to eat foods that are rich in iron."

The auction continued with a further two rounds. At the end of Round 4, the third part of the auction survey was distributed and completed by the participants. Next, participants were given the second information treatment stating that IBFM was developed using modern breeding techniques not involving GM:

Information Treatment 2: process-related information:

> "High iron ragi is a new ragi variety that has been developed by some renowned researchers using a method called "biofortification". The word "bio" means "life" and the word "fortification" means to "make strong". The idea of biofortification is to make crops more nutritious as they grow. This is achieved using modern breeding technologies. This is an improvement to ordinary fortification

where nutrients are just added to the food when the food is being processed. Importantly: First, iron-biofortification does not change the taste, appearance or the cooking properties of a crop. It only makes it more nutritious. Second, we can assure you that high-iron ragi is made WITHOUT the use of genetic modification!"

The auction continued with the last two rounds. At the end of the finger millet auction one of the auction rounds was randomly drawn as binding. The highest bidder of that round was announced as the "winner" of the auction and the corresponding second highest bid as the price to pay for the exchange of LFM with IBFM. However, because IBFM was not yet ready for consumption in 2017, we used a product dummy in order to maintain the non-hypothetical nature of the auctions. Hence, during the debriefing, participants were informed about the real nature of the product auctioned (LFM instead of IBFM) and the exchange with the winner was canceled. The experiment was closed when all participants received their monetary compensation.

2.4 Sample

A total of 120 people participated in the experiment, which took place on Sunday July 16th 2017 at the premises of a primary school in Madhugiri town, a village 100km from Bangalore, the capital of Karnataka. Participants were recruited two weeks before the experiment using convenience sampling. To be eligible for participation, participants needed to meet the following five criteria: Live in Madhugiri town; literate; at least 18 years of age; (jointly) responsible for household food purchases; and not involved in farming.

Out of 120 study participants, the data of 94 participants could be used for data analysis. As verified by the information obtained in the auction survey, 24 participants did not comply with the eligibility criteria of the study, and therefore were excluded from the analysis. For another two participants the data was incomplete.

2.5 Analysis of information effects and determinants of willingness to pay

WTP data is usually analyzed in two stages, with the first stage modeling the likelihood of a positive (non-zero) WTP using logistic regression and the second stage modeling actual (above zero) WTP using linear regression (Cragg, 1971). Given the low share of zero bids in our data (see section 3.2), we only modeled the second stage, excluding the participants with at least one zero bid ($n = 8$). Since observations were clustered by subject (six observations per subject) and could therefore not be considered independent, we used a linear mixed-effects model for the analysis of WTP (Vecchio and Annunziata, 2018). The function of a mixed-effects model accounts for the correlation between measurements by including individual specific parameter coefficients (or so-called random effects) and thus allowing for both within-subject and between-subject variability (Bauer, 2011; Crowder and Hand, 2017; Cudeck, 1996). In this study, we included a random effect on the intercept and estimated the following mixed-effects model using the restricted maximum likelihood (REML) approach:

$$\log(\mathrm{WTP_i}) = (\beta_0 + \mathrm{b_{i0}}) + \beta_1\mathrm{TRD1_i} + \beta_2\mathrm{TRD2_i} + \beta_3\mathrm{KNOWIHB_i} + \beta_4\mathrm{SKEPT_i}$$
$$+ \beta_5\mathrm{TRD1_i}*\mathrm{KNOWIHB_i} + \beta_6\mathrm{TRD2_i}*\mathrm{SKEPT_i} + \beta_7\mathrm{C\_AGE_i} + \beta_8\mathrm{INC_i} + \beta_9\mathrm{GEND_i}$$
$$+ \beta_{10}\mathrm{EDUC_i} + \beta_{11}\mathrm{ROUND_i} + \beta_{12}\mathrm{MF_i} + \beta_{13}\mathrm{ROOM_i} + \beta_{14}\mathrm{SESSION_i} + \varepsilon_\mathrm{i}$$

$i = 1, \ldots, n$ for observation i ($n = 86$).

$$b_{i0} \sim N(0, \Phi)$$
$$\epsilon_{it} \sim N(0, \Phi)$$

WTP_i denotes participant i's bid and is log transformed to normalize the right-skewed distribution of WTP values (see section 3.2). $(\beta_0 + b_{i0})$ is the intercept with random effect. $TRD1_i$ is a dummy for the first information treatment. It is zero in Round 1 and Round 2 and one thereafter. $TRD2_i$ is a dummy for the second information treatment. It is zero in Round 1, 2, 3 and 4 and one thereafter. $KNOWIHB_i$ is a dummy variable for prior knowledge about the health benefits of iron and $SKEPT_i$ is a dummy variable for skepticism toward new varieties. Due to the restricted sample size, we were selective on the socio-economic variables and only included the most important ones, specifically; C_AGE_i, an ordinal variable for age, INC_i, an ordinal variable for income, $GEND_i$, a dummy variable for gender, and $EDUC_i$, an ordinal variable for education. $ROUND_i$ is a numeric variable for auction round and is included here to control for increasing bids, a phenomenon found in most experimental auction markets with a repeated measures design (List and Shogren, 1999). For the sake of simplicity, it is assumed to be linear. MF_i is a numeric variable for the market feedback provided in the previous round and included here to control for "affiliated" bids, likewise a phenomenon discussed in the experimental auction literature (Milgrom and Weber, 1982). Finally, $Room_i$ – a dummy for room allocation – and $Session_i$ – a factor for session allocation – are included as controls, as the difference in auction facilitators (room) and the change in their performance over time (session) could have significantly affected WTP, despite our precautions. ϵ_i is the random error term that accounts for the random variation not explained by the model.

Information treatments were aimed to increase respondents' knowledge on the health benefits of iron ($TRD1_i$) and reduce or increase their possible skepticism toward IBFM ($TRD2_i$). Therefore we also analyzed the role prior knowledge ($KNOWIHB_i$) and skepticism ($SKEPT_i$) played in how treatments affected WTP by including two interaction terms, one between $TRD1$ and $KNOWIHB$ and another one between $TRD2$ and $SKEPT$.

All the analyses were performed using the software *R* (version 3.6.1; *R* Core Team (2019)).

3. Results

3.1 Sample characteristics

Tables 1 and 2 summarize the key sample characteristics.

The socio-economic data obtained indicate that study participants were parents of young families with a relatively high education and middle income. They were rather female (60%), young (76% below the age of 45, of which 68% female), highly educated (66% completed at least 13 years of education) and married (82%) and in 20% of the cases lived with at least one child below the age of five. They lived in a household with an average size of four people

Continuous variables	Definition	Mean	Std. deviation	Median	Min	Max	*n*
Socio demographics							
AGE	Age in number of years	38	11	37	18	68	94
HHSIZE	Number of people living in the household (including respondent)	4	1	4	2	9	94
Finger millet consumption							
FMCONSHH	Finger millet consumption per household per month in kg	13	11	10	0	70	94
FMCONSHHM	Finger millet consumption per household member per month in kg	3	2	3	0	12	94

Table 1. Socio-demographic and auction-related survey variables– continuous

Nominal variables	Definition	Levels	*n*	Valid %
Socio demographics				
C_AGE	Age classes	1. 18_27 years	17	18.09
		2. 28_36 years	29	30.85
		3. 37_43 years	23	24.47
		4. 44_68 years	25	26.60
GEND	Gender	1. Male	38	40.43
		0. Female	56	59.57
EDUC	Education levels	1. Up to 12 years	32	34.05
		2. 13–15 years	35	37.23
		3. More than 15 years	27	28.72
CHILD	Children below age five	1. Yes	19	20.21
		0. No	75	79.79
MAR	Marital status	1. Married	77	81.91
		0. Not married	17	18.09
INC	Income	1. No regular income	4	04.26
		2. Less than Rs. 10'000	21	22.34
		3. Rs. 10'000–20'000	32	34.04
		4. Rs. 20'001–30'000	17	18.09
		5. Rs. 30'001–40'000	8	08.51
		6. More than Rs. 40'000	12	12.77
Prior knowledge				
KNOWIP	Prior Knowledge about the purpose of iron in food	1. Yes	83	88.30
		0. No	11	11.70
KNOWIHB	Prior Knowledge about the health benefits of iron	1. Yes	80	85.11
		0. No	14	14.89
Iron supplements/anemia				
SUPP	Previous consumption of iron upplements by a household member (including respondent)	1. Yes	62	65.96
		0. No	32	34.04
ANEM	Previous occurrence of anemia in a household member (including respondent)	1. Yes	38	40.43
		0. No	56	59.57
Attitudes toward new varieties				
DEVEL	Assumption about how IBFM was developed	1. Genetic modification	17	18.09
		2. Fortification	1	01.06
		3. Modern breeding	63	67.02
		4. No idea	13	13.83
SKEPT	Skepticism toward new varieties	1. Rather or very skeptical	49	52.13
		0. Rather or not skeptical at all	45	47.87

Table 2. Socio-demographic and auction-related survey variables– nominal

and more than half disposed of a monthly household income between Rs. 10'000 and 30'000 (between US$ 145 and US$ 434). In comparison to World Bank data, the latter corresponds to the income of a developing world's lower middle class family household (Ravallion, 2009).

Furthermore, the data indicates that iron deficiency is an important issue for the people who participated in this study. More than half of the participants (66%) stated that at least one household member (including themselves) had taken iron supplements before. More than one-third (40%) stated that at least one household member (including themselves) had suffered from anemia. Almost all of them passed the two knowledge tests on iron, which they took prior to the basic nutrition information and Information Treatment 1, respectively. In total, 88% of the respondents knew that iron is an important nutrient for the human body and 83% knew that iron strengthens the human body. Given the high level of education in the sample this was to be expected.

The data also indicate that finger millet plays an important role in participants' diet (average monthly finger millet consumption of 3kg per household member). The results also provide evidence for skepticism toward new varieties. There was a considerable share of participants who were either rather or very skeptical toward new varieties (52%). In addition, prior to the provision of process-related information, more than half of the participants (67%) assumed IBFM to have been developed using modern breeding techniques, only about a fifth assumed it to to be GM, and the rest indicated that they did not know.

3.2 Summary of willingness to pay for iron-biofortified finger millet

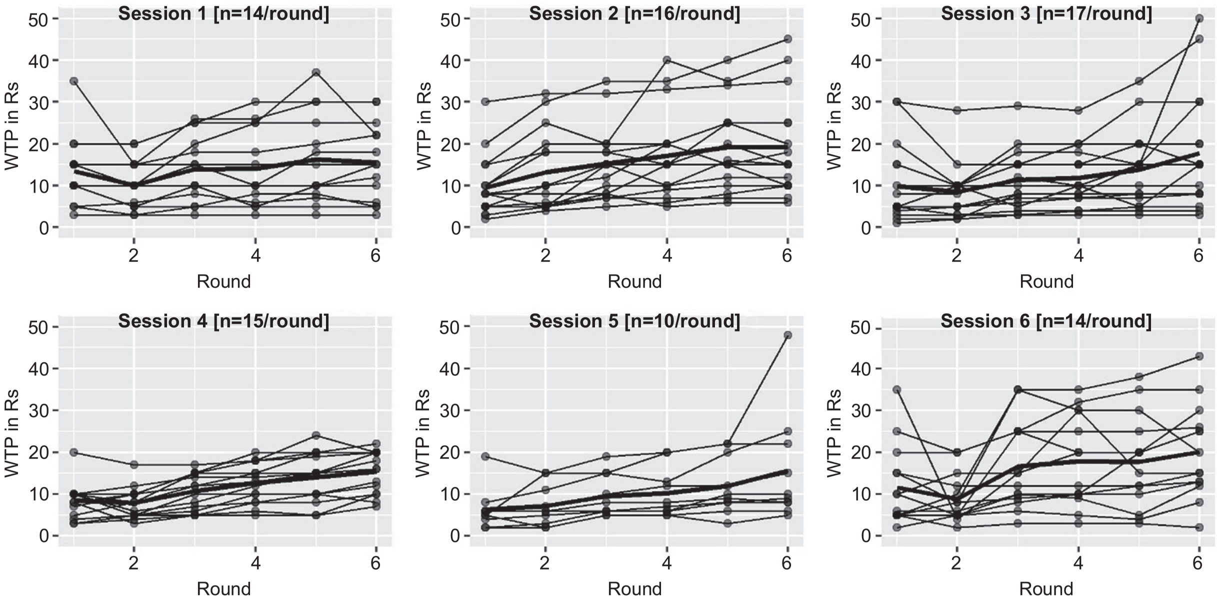
Table 3 summarizes the WTP for each round. With 2% in Round 6, the share of zero bids was rather low and decreasing with increasing round and information, which indicates participants' clear preference for IBFM over LFM. As indicated by the mean of non-zero bids in Round 2, 4 and 6, participants' WTP a premium for 1kg of IBFM equaled Rs. 9.34 with basic nutrition information only, Rs. 13.56 with additional health-related information and Rs. 16.47 with additional process-related information. Based on a market price of Rs. 35 for 1kg of LFM, this corresponds to premiums of 27%, 39 and 47%, respectively. From all 94 participants, 86 were willing to pay a premium for IBFM in all six rounds. Figure 2 visualizes their bid values as well as the average bid value per round for each experimental session. Noteworthy are the rather strong between-subject variability and positive trend of bid values as well as the downward shift after Round 1 and upward shift after Round 2 in some sessions.

3.3 The effect of information and other determinants on willingness to pay for iron-biofortified finger millet

The results of the model described in section 2.5 are shown in Table 4 and were generated using the function lmer from the lme4 package (Bates *et al.*, 2015). The results indicate that Information Treatment 1 had a significant, positive effect on the WTP. The same holds for the variable $ROUND_i$. This implicates, that the upward shift after Round 2 can be attributed to both Information Treatment 1 and round effect. Another variable, which had a significant, positive effect, is income. However, the effect is only attributable to the highest income group, which had a significantly [2] higher WTP than income group 1 through 4 but with only $n = 12$ respondents, so the result must be interpreted with care. Skepticism toward new varieties,

Auction round	Round 1	Round 2	Round 3	Round 4	Round 5	Round 6
n	94	94	94	94	94	94
Average bid (in Rs.)	9.26	8.74	12.12	13.13	14.55	16.12
Premiums w/o zero bids	26%	25%	35%	38%	42%	46%
Std deviation (in Rs.)	7.78	6.69	8.09	8.91	9.77	11.27
Median (in Rs.)	6.50	7.00	10.00	10.00	13.50	15.00
Min (in Rs.)	0.00	0.00	0.00	0.00	0.00	0.00
Max (in Rs.)	35.00	32.00	35.00	40.00	40.00	50.00
Zero bids (#)	6	6	3	3	3	2
Zero bids (%)	6.38	6.38	3.19	3.19	3.19	2.13
Av. bid w/o zero bids (in Rs.)	9.89	9.34	12.52	13.56	15.03	16.47
Premiums w/o zero bids	28%	27%	36%	39%	43%	47%
Std deviation w/o zero bids (in Rs.)	7.64	6.50	7.91	8.73	9.56	11.14
Median w/o zero bids (in Rs.)	8.00	8.00	10.00	10.00	15.00	15.00

Table 3. Overview of WTP statistics per auction round in Rs. with and without zero bids



Note(s): Each session included 20 participants in total. The sample size of each session is, however, lower here, because, overall, 24 participants had to be excluded from the analysis, as they did not comply with the eligibility criteria of the study, and for another two participants the data was incomplete (see section 2.4). Furthermore, six participants had a WTP of zero, which are also excluded here

Figure 2.
Positive, individual bid values and sample average across rounds

Variable	Coefficient	Lower bound (2.5%)	Upper bound (97.5%)	Std. Error	*p*-value
TRD1_1 (ref = 0)	0.40***	0.17	0.63	0.12	0.001
TRD2_1 (ref = 0)	0.06	−0.08	0.20	0.07	0.421
KNOWIHB_1 (ref = 0)	−0.14	−0.59	0.31	0.25	0.577
SKEPT_1 (ref = 0)	−0.37***	−0.61	−0.13	0.13	0.007
C_AGE_2 (ref = 1)	−0.31*	−0.63	0.02	0.18	0.099
C_AGE_3 (ref = 1)	−0.45**	−0.80	−0.09	0.20	0.028
C_AGE_4 (ref = 1)	−0.63***	−1.02	−0.25	0.22	0.005
INC_2 (ref = 1)	0.45	−0.30	1.20	0.42	0.287
INC_3 (ref = 1)	0.48	−0.24	1.21	0.41	0.243
INC_4 (ref = 1)	0.46	−0.29	1.21	0.42	0.277
INC_5 (ref = 1)	0.53	−0.25	1.32	0.44	0.232
INC_6 (ref = 1)	1.09**	0.31	1.86	0.44	0.015
GEND_1 (ref = 0)	−0.03	−0.28	0.21	0.14	0.810
EDUC_2 (ref = 1)	−0.26	−0.54	0.03	0.16	0.113
EDUC_3 (ref = 1)	−0.37**	−0.69	−0.05	0.18	0.043
ROUND	0.07**	0.00	0.13	0.03	0.046
MF	−0.00	−0.01	0.01	0.00	0.472
ROOM_1 (ref = 0)	−0.22	−0.46	0.02	0.14	0.105
SESSION_2 (ref = 1)	−0.08	−0.36	0.21	0.16	0.635
SESSION_3 (ref = 1)	−0.01	−0.28	0.24	0.15	0.919
TRD1_1*KNOWIHB_1	−0.14	−0.35	0.07	0.11	0.200
TRD2_1*SKEPT_1	0.02	−0.10	0.13	0.06	0.770
Constant	2.49***	1.57	3.40	0.51	0.000
Individual variance	0.29				
Residual variance	0.10				
rho (individual variance as fraction of total)	0.74				
Hausman chi-squared statistic	0.000 (df = 1)				
Marginal/ conditional R^2	0.31/0.82				
AIC	612.30				
n	86 × 6 = 516				

Note(s): The dependent variable is log(WTP); for dummy and factor variables the treatment contrast is used, so that the first level operates as the reference level and coefficients can be interpreted as the difference from the reference level; *, **, *** denote statistical significance at 0.1, 0.05, 0.01 respectively; The sample size is only $n = 86$ here, because six participants bid zero (and are therefore excluded from the regression) and because 24 participants had to be excluded from the overall analysis, as they did not comply with the eligibility criteria of the study. For another two participants the data was incomplete

Table 4.
Results of linear mixed-effects model

education and age all had a significant, negative effect on WTP. Information Treatment 2 did not have a significant effect, which might be due to the non-randomization of treatments and the resulting order effect, as mentioned in section 2.2. Also prior knowledge on the health benefits of iron, gender, market feedback and the two interaction terms were not found to be significant. Again, the results of $KNOWIHB_i$ not having any significant effect must be treated with care, as the number of respondents with no prior knowledge was rather small ($n = 14$). However, the result is in line with De Steur *et al.* (2012). The reason for the downward shift after Round 1 is not clear, but could be attributed to the market feedback, which was provided at the end of the round. Even though market feedback was insignificant overall, an initial “dampening” effect seems plausible, which is not picked up by the model, meaning that some participants tended to overbid at first and then corrected their bid once the first market feedback was provided.

Overall, the mixed-effects model performs well and can be considered appropriate for the data. According to the marginal and conditional R-squared measures, which were calculated using the function r.squaredGLMM from the package MuMIn (Nakagawa *et al.*, 2017), the fixed effects account for 31% of the variance and the random effect for another 51%. Furthermore, the AIC estimate is significantly lower (−34%) for the model with than the one without random effect and the Hausman test is significant, which both supports the inclusion of the random effect. According to the Tukey-Anscombe and Q-Q plots, the model also meets the homoscedasticity and normality assumptions of linear regression. The generalized variance inflation factor (GVIF) to measure the degree of multicollinearity was calculated using the function vif from package car (Fox and Weisberg, 2019). It is smaller than 5 for each variable that is included in the model indicating that there is no evidence of multicollinearity [3].

Since the model contains a random effect and the dependent variable is log transformed, the interpretation of coefficients is not straightforward. To estimate the size and relevance of the effects, Figure 3 visualizes them based on the back-transformed predicted marginal WTP values which were calculated for each significant variable, using the function ggeffect from the package ggeffects (Lüdecke, 2018). Whereas the effects seem to be relevant, there are also relatively large confidence intervals, indicating that prediction uncertainty is relatively high.

4. Discussion

Our results suggest that non-farming consumers' are willing to pay "a good price" for IBFM, in spite of rather low income levels and substantial general skepticism toward new varieties. First of all, there was a very low share of participants not willing to pay a premium for IBFM (only 2% in the final round). Second, based on a market price of Rs. 35, the average premium non-farming consumers were willing to pay was 27% (+Rs. 9.34) and could be significantly increased through the provision of health-related information. Similar values have been reported by other experimental auction studies on WTP for biofortified staple crops in developing countries. For instance, De Steur *et al.* (2012) found a premium of 34% for the improved (40 times higher) folate content in rice in China, which went up to 46% with the provision of health-related information. Banerji *et al.* (2016) found a premium of 29% for the improved iron content in pearl millet in India, including health-related information, and De Groote *et al.* (2011) a premium of 24% for the improved provitamin A content in maize in Africa, also including health-related information. These study results should be compared with care due to differences in target group, crop-country-micronutrient combination tested and auction design and mechanism used (De Steur *et al.*, 2016). For instance, 2nd price auctions can lead to higher WTP values than BDM auctions (Lusk *et al.*, 2004a) and providing participants with a monetary compensation can increase their WTP due to "windfall gains" (Clark, 2002). Although, according to a recent study by Banerji *et al.* (2018), these effects are not considered "economically meaningful" within a given context.

Even though skepticism toward new crop varieties was found to be high (52% of the respondents stated to be rather or very skeptical), it only had a small negative effect on WTP. Still we consider it important to discuss possible reasons for respondents' skepticism here. One reason for their skepticism could be negative attitudes toward new (breeding) technologies. However, our results as well as those from past literature suggest that this is not the case. First of all, respondents were equally skeptical, irrespective of the prior assumption regarding the use of GM in breeding and did not change their WTP after the provision of the information about the (non-GM) breeding method used. This suggests that non-farming consumers' skepticism toward new crop varieties was independent of the use of GM. Furthermore, it suggests that the process-related information was irrelevant for them, be it because the information was not new or did increase neither their technology-related perceived risks nor benefits. Second, past literature found Asian consumers' risk perceptions of GM to be rather low and their benefit perceptions to be rather high (see, e.g. Frewer *et al.*

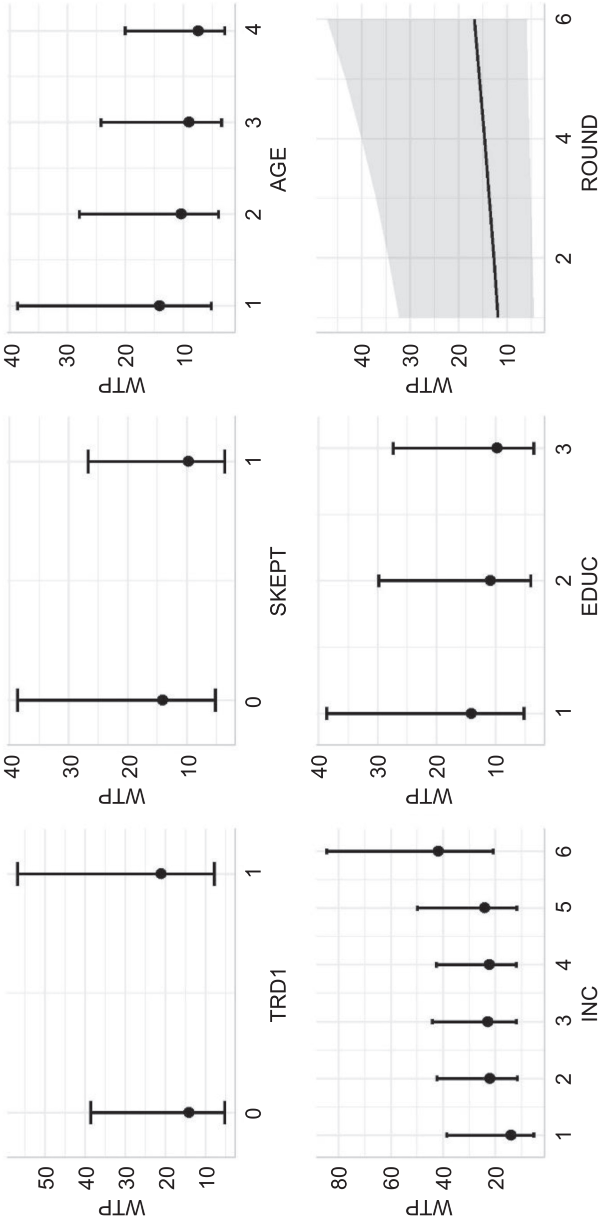


Figure 3.
Visualization of back-transformed predicted marginal WTP values in Rs. with confidence intervals

(2013)). For new, non-GM breeding techniques their perceived risks are expected to be even lower as they are probably perceived as less "unnatural" than those involving GM (Lucht, 2015). Another possible reason for non-farming consumers' skepticism toward new crop varieties could also be the crops' novelty and the resulting uncertainty about taste, cooking properties, etc. (Lusk and Shogren, 2007; Owusu *et al.*, 2017). A simple statement about a crop's sensory equivalence to local, well-known varieties (external information), as provided in the basic nutrition information in this study, might not suffice to replace a consumer's direct experience with the product (internal information) (Lange *et al.*, 2000; Scholderer *et al.*, 2000). One way to deal with this in an experimental setting is to give consumers the opportunity to taste the product (Combris *et al.*, 2009), given that the product is ready for consumption, which was not the case in this study. Tasting has even proven effective to increase the WTP for GM crops (Grunert *et al.*, 2003). One more possible explanation for non-farming consumers skepticism toward new varieties could be their mistrust toward the national or foreign governments, who financed the research, the universities, where the research was conducted, or the national or foreign food industries, who might be seen as the main beneficiaries (Siegrist, 2008). In this case it is important to identify the bodies or institutions non-farming consumers trust in and brand or certify the product's information accordingly. For instance, Indian consumers have been found to prefer international to state-level branding or certification (Banerji *et al.*, 2016). In this study no certification or branding was used, however, the research was led by a Swiss research team, which was present on the experimental site and possibly raised participants' trust. Hence, the skepticism found is most likely due to the crops' novelty and not respondents' mistrust, be it toward breeding technologies or toward governments, researchers, or food industries.

Respondents in income group 6 (monthly income above Rs. 40'000) were found to have a significantly higher WTP than respondents in income groups 1 through 4 (monthly income up to Rs. 30'000). In contrast, among income groups 1 through 5, no significant differences in WTP were found. This indicates that income needs to vary substantially to be relevant for the WTP in the context of biofortified staple crops (De Steur *et al.*, 2012). Furthermore, young respondents (from 18 up to 27 years old) were found to have a significantly higher WTP than older ones. This suggests that a micronutrient-rich diet is perceived as more relevant by young families. Contrary to Banerji *et al.* (2016), we found no significant difference in the WTP between women and men. This result is as expected, since we prompted participants to answer in their role as household member. However, the negative effect of education is surprising since better educated consumers might be expected to have more nutritional knowledge as well as more objective knowledge about the risks and benefits of a technology and therefore value biofortified foods more compared to less educated consumers (Linnemann *et al.*, 1999). However, previous research has shown that more educated consumers do not necessarily have more nutritional knowledge than less educated ones (Pounis *et al.*, 2011).

This study faces several limitations. First of all, we were not able to use a control group due to budget and time constraints. The same limitation was also encountered in other multiple-bid auction studies with information shocks (Bruschi *et al.*, 2015; De Steur *et al.*, 2012; Kajale and Becker, 2014). An increase in WTP after information provision cannot be solely attributed to the information treatment due to potential round and market feedback effects, which is why a control group is highly recommended (Lusk *et al.*, 2004a). Following the approach used in Alfnes and Rickertsen (2003), we tried to solve this issue of confounded effects by controlling for auction round and market feedback in the regression. In fact, round turned out to have a positive significant effect on WTP. Another design-related limitation is that we did not randomize the treatments, which can have led to an order effect impossible to control for (West *et al.*, 2004). Hence, the ineffectiveness of the second process-related information treatment could also be attributed to the fixed order of treatments.

5. Conclusion

For the acceptance of biofortified crops by smallholder farmers, the possibility to sell them at "a good market price" is very important. Thus, non-farming consumers' WTP a premium for biofortified crops on the market is a key aspect. Our study shows that non-farming consumers are willing to pay "a good price" for IBFM millet. With an average premium of 27% the price non-farming consumers are willing to pay is by far better than the current market price of Rs. 35. The study also confirms the importance of informing and educating consumers about the health benefits of biofortified crops (Garcia-Casal *et al.*, 2017). However, it also suggests that there is substantial skepticism toward new crop varieties and that more skepticism leads to lower WTP, even though the effect is relatively small. Also education has been found to have a negative effect on WTP. For the acceptance of new foods, particularly if they have been developed using a technical process, trust plays an important role (Siegrist, 2008). Product tasting (Combris *et al.*, 2009; Grunert *et al.*, 2003), even though no change in taste is expected, as well as information branding or certification (Banerji *et al.*, 2016) are possible measures to raise consumers' trust. Future research may wish to further examine the reasons behind the lower WTP of more skeptical and/or educated consumers and the potential of product tasting and information branding as measures to raise their WTP.

This study focused on non-farming consumers' WTP for biofortified staple crops as one important success factor of biofortification. Because if a biofortified crop sells at a "good market price", this is an important motivation for farmers to grow the crop (Asare-Marfo *et al.*, 2010). Another important determinant of farmers' willingness to grow a crop is its potential to achieve "good yields" (Asare-Marfo *et al.*, 2010). However, the yields of millets have generally been lower than the yields of staples like rice and wheat (Grovermann *et al.*, 2018). A solution would be to embed the promotion of an improved millet variety in an overall strategy for boosting millet use more generally, including improved growing practices to achieve better yields (Battese *et al.*, 2017; Grovermann *et al.*, 2018). Apart from "good market prices" and "good yields", farmers' long term access to the seeds of biofortified crops is also an important success factor of biofortification which needs to be addressed (Okello *et al.*, 2018).

Notes

1. Instructions were compiled following the examples in Lusk and Shogren (2007) and the instructions published by De Steur *et al.* (2012) and are available from the author on request.
2. Contrasts were calculated using Bonferroni correction.
3. Education (EDUC) and income (INC), education (EDUC) and knowledge on the health benefits of iron (KNOWIHB), and education (EDUC) and skepticism (SKEPT) are not significantly correlated.

References

Alfnes, F. and Rickertsen, K. (2003), "European consumers' willingness to pay for U.S. beef in experimental auction markets", *American Journal of Agricultural Economics*, Vol. 85, pp. 396-405.

Asare-Marfo, D., Birol, E. and Roy, D. (2010), "Investigating farmers' choice of pearl millet varieties in india to inform targeted biofortification interventions: modalities of multi-stakeholder data collection", Discussion Paper Series - Environmental Economy and Policy Research, University of Cambridge, No. 51, p. 33.

Asare-Marfo, D., Birol, E., Gonzalez, C., Moursi, M., Perez, S., Schwarz, J. and Zeller, M. (2013), "Prioritizing countries for biofortification interventions using country-level data", *International Food Policy Research Institute (IFPRI)*.

Bala Ravi, S., Hrideek, T., Kumar, A., Prabhakaran, T., Mal, B. and Padulosi, S. (2010), "Mobilizing neglected and underutilized crops to strengthen food security and alleviate poverty in India", *Indian J. Plant Genet. Resour.*, Vol. 23 No. 1, pp. 110-116.

Banerji, A., Chowdhury, S., De Groote, H., Meenakshi, J., Tomlins, K., Haleegoah, J. and Ewool, M. (2013), "Using elicitation mechanisms to estimate the demand for nutritious maize: evidence from experiments in rural ghana", (HarvestPlus Working Paper No. 10).

Banerji, A., Birol, E., Karandikar, B. and Rampal, J. (2016), "Information, branding, certification, and consumer willingness to pay for high-iron pearl millet: evidence from experimental auctions in Maharashtra, India", *Food Policy*, Vol. 62, pp. 133-141, doi: 10.1016/j.foodpol.2016.06.003.

Banerji, A., Chowdhury, S., De Groote, H., Meenakshi, J., Haleegoah, J. and Ewool, M. (2018), "Eliciting willingness-to-pay through multiple experimental procedures: evidence from lab-in-the-field in rural Ghana", *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, Vol. 66 No. 2, pp. 231-254.

Bates, D., Maechler, M., Bolker, B. and Walke, S. (2015), "Fitting linear mixed-effects models using lme 4", *Statistical Software*, Vol. 67 No. 1, pp. 1-48, doi:10.18637/jss.v067.i01.

Battese, G.E., Nazli, H. and Smale, M. (2017), "Factors influencing the productivity and efficiency of wheat farmers in Punjab, Pakistan", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 7 No. 2, pp. 82-98, doi:10.1108/jadee-12-2013-0042.

Bauer, D.J. (2011), "Evaluating individual differences in psychological processes", *Current Directions in Psychological Science*, Vol. 20 No. 2, pp. 115-118.

Birol, E., Asare-Marfo, D., Karandikar, B. and Roy, a. D. (2011), "A latent class approach to investigating farmer demand for biofortified staple food crops in developing countries: the case of high-iron pearl millet in Maharashtra, India", HarvestPlus Working Paper 7.

Birol, E., Asare-Marfo, D., Karandikar, B., Roy, D. and Diressie, M.T. (2015a), "Investigating demand for biofortified seeds in developing countries: high-iron pearl millet in India", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 5 No. 1, pp. 24-43.

Birol, E., Meenakshi, J., Oparinde, A., Perez, S. and Tomlins, K. (2015b), "Developing country consumers' acceptance of biofortified foods: a synthesis", *Food Security*, Vol. 7 No. 3, pp. 555-568.

Bouis, H.E., Hotz, C., McClafferty, B., Meenakshi, J.V. and Pfeiffer, W.H. (2011), "Biofortification: a new tool to reduce micronutrient malnutrition", *Food and Nutrition Bulletin*, Vol. 32, Supplement 1, pp. 31S-40S.

Bruschi, V., Teuber, R. and Dolgopolova, I. (2015), "Acceptance and willingness to pay for health-enhancing bakery products–Empirical evidence for young urban Russian consumers", *Food Quality and Preference*, Vol. 46, pp. 79-91.

Chowdhury, S., Meenakshi, J.V., Tomlins, K.I. and Owori, C. (2011), "Are consumers in developing countries willing to pay more for micronutrient-dense biofortified foods? Evidence from a field experiment in Uganda", *American Journal of Agricultural Economics*, Vol. 93 No. 1, pp. 83-97, doi: 10.1093/ajae/aaq121.

Clark, J. (2002), "House money effects in public good experiments", *Experimental Economics*, Vol. 5 No. 3, pp. 223-231.

Combris, P., Bazoche, P., Giraud-Héraud, E. and Issanchou, S. (2009), "Food choices: what do we learn from combining sensory and economic experiments?", *Food Quality and Preference*, Vol. 20 No. 8, pp. 550-557.

R Core Team (2019), *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, available at: https://www.blopig.com/blog/2013/07/citing-r-packages-in-your-thesispaperassignments/#:~:text=citation()%20To%20cite%20R,R%2Dproject.org%2F.

Cragg, J.G. (1971), "Some statistical models for limited dependent variables with application to the demand for durable goods", *Econometrica*, Vol. 39 No. 5, pp. 829-844, doi:10.2307/1909582.

Crowder, M.J. and Hand, D.J. (2017), *Analysis of Repeated Measures*, Routledge, Abingdon.

Cudeck, R. (1996), "Mixed-effects models in the study of individual differences with repeated measures data", *Multivariate Behavioral Research*, Vol. 31 No. 3, pp. 371-403.

Das, A., Laha, S., Mandal, S., Pal, S. and Siddiqui, M.W. (2018), "Preharvest biofortification of horticultural crops", in Siddiqui, M.W. (Ed.), *Preharvest Modulation of Postharvest Fruit and Vegetable Quality*, Academic Press, London, pp. 381-434.

De Groote, H. and Kimenju, S.C. (2008), "Comparing consumer preferences for color and nutritional quality in maize: application of a semi-double-bound logistic model on urban consumers in Kenya", *Food Policy*, Vol. 33 No. 4, pp. 362-370.

De Groote, H., Kimenju, S.C. and Morawetz, U.B. (2011), "Estimating consumer willingness to pay for food quality with experimental auctions: the case of yellow versus fortified maize meal in Kenya", *Agricultural Economics*, Vol. 42 No. 1, pp. 1-16.

De Steur, H., Gellynck, X., Storozhenko, S. and Lambert, W. (2010), "Willingness to accept and purchase genetically modified rice with high folate content in shanxi province, China", *Appetite*, Vol. 54, pp. 118-125.

De Steur, H., Gellynck, X., Feng, S., Rutsaert, P. and Verbeke, W. (2012), "Determinants of willingness-to-pay for GM rice with health benefits in a high-risk region: evidence from experimental auctions for folate biofortified rice in China", *Food Quality and Preference*, Vol. 25, pp. 87-94.

De Steur, H., Wesana, J., Blancquaert, D., Van Der Straeten, D. and Gellynck, X. (2016), "Methods matter: a meta-regression on the determinants of willingness-to-pay studies on biofortified foods", *Annals of the New York Academy of Sciences)*, doi:10.1111/nyas.13277.

De Steur, H., Blancquaert, D., Stove, C., Lambert, W., Van Der Straeten, D. and Gellynck, X. (2017), "Should GM rice with nutrition benefits Be deployed? Findings from biotech and socio-economic research", in Adenle, A., Morris, E. and Murphy, D. (Eds), *Genetically Modified Organisms in Developing Countries: Risk Analysis and Governance*, Cambridge University Press, Cambridge, pp. 139-150.

Divya, G.M. (2011), "Growth and instability analysis of finger millet crop in Karnataka", M., Sc. (Agri) Thesis, Agricultural Economics, University of Agricultural Sciences Bangalore.

Finkelstein, J.L., Haas, J.D. and Mehta, S. (2017), "Iron-biofortified staple food crops for improving iron status: a review of the current evidence", *Current Opinion in Biotechnology*, Vol. 44, pp. 138-145, doi: 10.1016/j.copbio.2017.01.003.

Fox, J. and Weisberg, S. (2019), *An {R} Companion to Applied Regression*, 3 ed., Sage, Thousand Oaks CA.

Frewer, L.J., van der Lans, I.A., Fischer, A.R., Reinders, M.J., Menozzi, D., Zhang, X., . . . and Zimmermann, K.L. (2013), "Public perceptions of agri-food applications of genetic modification–a systematic review and meta-analysis", *Trends in Food Science and Technology*, Vol. 30 No. 2, pp. 142-152.

Garcia-Casal, M.N., Peña-Rosas, J.P. and Giyose, B. (2017), "Staple crops biofortified with increased vitamins and minerals: considerations for a public health strategy", *Annals of the New York Academy of Sciences*, pp. 3-13, doi:10.1111/nyas.13293.

Grovermann, C., Umesh, K., Quiédeville, S., Kumar, B. and Moakes, S. (2018), "The economic reality of underutilised crops for climate resilience, food security and nutrition: assessing finger millet productivity in India", *Agriculture*, Vol. 8 No. 9, p. 131.

Grunert, K.G., Bredahl, L. and Scholderer, J. (2003), "Four questions on European consumers' attitudes toward the use of genetic modification in food production", *Innovative Food Science and Emerging Technologies*, Vol. 4 No. 4, pp. 435-445.

Hanemann, W.M. (2003), "Willingness to pay and willingness to accept: how much can they differ? Reply, *The American Economic Review*, Vol. 93 No. 1, pp. 464-464, doi: 10.1257/000282803321455449.

Herrington, C., Lividini, K., Angel, M.D. and Birol, E. (2019), "Prioritizing Countries for Biofortification Interventions: Biofortification Priority Index", 2nd ed. (BPI 2.0). HarvestPlus Working Paper.

Jaeger, S.R. and Harker, F.R. (2005), "Consumer evaluation of novel kiwifruit: willingness-to-pay", *Journal of the Science of Food and Agriculture*, Vol. 85 No. 15, pp. 2519-2526.

Kajale, D.B. and Becker, T.C. (2014), "Effects of information on young consumers' willingness to pay for genetically modified food: experimental auction analysis", *Ecology of Food and Nutrition*, Vol. 53 No. 3, pp. 292-311.

Lange, C., Issanchou, S. and Combris, P. (2000), "Expected versus experienced quality: trade-off with price", *Food Quality and Preference*, Vol. 11 No. 4, pp. 289-297.

Linnemann, A.R., Meerdink, G., Meulenberg, M.T.G. and Jongen, W.M.F. (1999), "Consumer-oriented technology development", *Trends in Food Science and Technology*, Vol. 9, pp. 409-414.

List, J.A. and Shogren, J.F. (1999), "Price information and bidding behavior in repeated second-price auctions", *American Journal of Agricultural Economics*, Vol. 81 No. 4, pp. 942-949.

Lucht, J. (2015), "Public acceptance of plant biotechnology and GM crops", *Viruses*, Vol. 7 No. 8, pp. 4254-4281.

Lüdecke, D. (2018), "Ggeffects: tidy data frames of marginal effects from regression models", *Open Source Software*, Vol. 3 No. 26, doi:10.21105/joss.00772.

Lusk, J.L. (2003), "Using experimental auctions for marketing applications: a discussion", *Journal of Agricultural and Applied Economics*, Vol. 35 No. 2, pp. 349-360.

Lusk, J.L. and Shogren, J.F. (2007), *Experimental Auctions: Methods and Applications in Economic Research and Marketing Research*, Cambridge University Press, Cambridge.

Lusk, J.L., Feldkamp, T. and Schroeder, T.C. (2004a), "Experimental auction procedure: impact on valuation of quality differentiated goods", *American Journal of Agricultural Economics*, Vol. 86 No. 2, pp. 389-405.

Lusk, J.L., House, L.O., Valli, C., Jaeger, S.R., Moore, M., Morrow, J.L. and Traill, W.B. (2004b), "Effect of information about benefits of biotechnology on consumer acceptance of genetically modified food: evidence from experimental auctions in the United States, England, and France", *European Review of Agricultural Economics*, Vol. 31 No. 2, pp. 179-204, doi: 10.1093/erae/31.2.179.

Lusk, J.L., Alexander, C. and Rousu, M.C. (2007), "Designing experimental auctions for marketing research: the effect of values, distributions, and mechanisms on incentives for truthful bidding", *Review of Marketing Science*, Vol. 5, pp. 1-30.

Meenakshi, J.V., Johnson, N., Manyong, V.M., Groote, H.D., Javelosa, J., Yanggen, D., . . . and Meng, E. (2010), "How cost-effective is biofortification in combating micronutrient malnutrition?", *An ex-ante assessment. World Development*, Vol. 38 No. 1, pp. 64-75.

Milgrom, P.R. and Weber, R.J. (1982), "A theory of auctions and competitive bidding", *Econometrica: Journal of the Econometric Society*, Vol. 50 No. 5, pp. 1089-1122.

Mogendi, J.B., De Steur, H., Gellynck, X. and Makokha, A. (2016a), "Consumer evaluation of food with nutritional benefits: a systematic review and narrative synthesis", *International Journal of Food Sciences and Nutrition*, Vol. 67 No. 4, pp. 355-371.

Mogendi, J.B., De Steur, H., Gellynck, X. and Makokha, A. (2016b), "A novel framework for analysing stakeholder interest in healthy foods: a case study on iodine biofortification", *Ecology of Food and Nutrition*, Vol. 55 No. 2, pp. 182-208.

Murekezi, A., Oparinde, A. and Birol, E. (2017), "Consumer market segments for biofortified iron beans in Rwanda: evidence from a hedonic testing study", *Food Policy*, Vol. 66, pp. 35-49.

Nakagawa, S., Johnson, P.C. and Schielzeth, H. (2017), "The coefficient of determination R^2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded", *Journal of The Royal Society Interface*, Vol. 14 No. 134, p. 20170213.

Okello, J.J., Jogo, W., Kwikiriza, N. and Muoki, P. (2018), "Motivations and cognitive models associated with decentralized seed multiplication: experiences from biofortified sweetpotato vine multipliers in Kenya and Ethiopia", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 8 No. 4, pp. 626-641, doi:10.1108/jadee-06-2017-0058.

Oparinde, A., Birol, E., Murekezi, A., Katsvairo, L., Diressie, M.T., Nkundimana, J.D. and Butare, L. (2015), "Consumer acceptance of biofortified iron beans in rural rwanda: experimental evidence", HarvestPlus Working Paper 18.

Oparinde, A., Banerji, A., Birol, E. and Ilona, P. (2016), "Information and consumer willingness to pay for biofortified yellow cassava: evidence from experimental auctions in Nigeria", *Agricultural Economics*, Vol. 47, pp. 215-233.

Owusu, V., Owusu-Sekyere, E., Donkor, E., Darkwaah, N.A. and Adomako-Boateng, D. (2017), "Consumer perceptions and willingness to pay for cassava-wheat composite bread in Ghana A hedonic pricing approach", *Journal of Agribusiness in Developing and Emerging Economies*, Vol. 7 No. 2, pp. 115-134, doi:10.1108/jadee-11-2014-0044.

Padulosi, S., Mal, B., King, O. and Gotor, E. (2015), "Minor millets as a central element for sustainably enhanced incomes, empowerment, and nutrition in rural India", *Sustainability*, Vol. 7 No. 7, pp. 8904-8933.

Pérez, S., Oparinde, A., Birol, E., Gonzalez, C. and Zeller, M. (2018), "Consumer acceptance of an iron bean variety in Northwest Guatemala: the role of information and repeated messaging", *Agricultural and Food Economics*, Vol. 6 No. 1, p. 14.

Peters, D.H., Tran, N.T. and Adam, T. (2013), *Implementation Research in Health: A Practical Guide*, World Health Organization, Geneva.

Pounis, G.D., Makri, S., Gougias, L., Makris, H., Papakonstantinou, M., Panagiotakos, D.B. and Kapsokefalou, M. (2011), "Consumer perception and use of iron fortified foods is associated with their knowledge and understanding of nutritional issues", *Food Quality and Preference*, Vol. 22 No. 7, pp. 683-688.

Ravallion, M. (2009), "The developing world's bulging (but vulnerable) middle class", in Group, D.R. (Ed.), *Policy Research Working Paper*, World Bank, Washington, DC.

Roosen, J., Fox, J.A., Hennessy, D.A. and Schreiber, A. (1998), "Consumers' valuation of insecticide use restrictions: an application to apples", *Journal of Agricultural and Resource Economics*, Vol. 23 No. 2, pp. 367-384.

Sakamma, S., Umesh, K.B., Girish, M.R., Ravi, S.C., Satishkumar, M. and Bellundagi, V. (2018), "Finger millet (eleusine coracana L. Gaertn.) production system: status, potential, constraints and implications for improving small farmer's welfare", *Journal of Agricultural Science*, Vol. 10 No. 1, pp. 162-179.

Scholderer, J., Bredahl, L. and Frewer, L. (2000), "Ill-founded models of consumer choice in communication about food biotechnology", Paper presented at the *Proceedings of the 5th International Conference on Corporate and Marketing Communications*.

Shogren, J.F., Fox, J.A., Hayes, D.J. and Kliebenstein, J.B. (1994a), "Bid sensitivity and the structure of the Vickrey auction", *American Journal of Agricultural Economics*, Vol. 76 No. 5, pp. 1089-1095.

Shogren, J.F., Shin, S.Y., Hayes, D.J. and Kliebenstein, J.B. (1994b), "Resolving differences in willingness to pay and willingness to accept", *The American Economic Review*, Vol. 84 No. 1, pp. 255-270.

Shogren, J.F., Margolis, M., Koo, C. and List, J.A. (2001), "A random *n*th-price auction", *Journal of Economic Behavior and Organization*, Vol. 46, pp. 409-421.

Siegrist, M. (2008), "Factors influencing public acceptance of innovative food technologies and products", *Trends in Food Science and Technology*, Vol. 19 No. 11, pp. 603-608.

Stein, A.J., Meenakshi, J., Qaim, M., Nestel, P., Sachdev, H. and Bhutta, Z.A. (2008), "Potential impacts of iron biofortification in India, *Social Science and Medicine*, Vol. 66 No. 8, pp. 1797-1808.

Swiss Agency for Development and Cooperation (SDC) (2016), "Indo Swiss collaboration in biotechnology (ISCB)", available at: https://www.eda.admin.ch/dam/deza/en/documents/themen/landwirtschaft-ernaehrungssicherheit/ISCB-infosheet_EN.pdf.

Talsma, E.F., Melse-Boonstra, A. and Brouwer, I.D. (2017), "Acceptance and adoption of biofortified crops in low- and middle-income countries: a systematic review", *Nutrition Reviews*, Vol. 75 No. 10, pp. 798-829, doi: 10.1093/nutrit/nux037.

Vecchio, R. and Annunziata, A. (2018), *Experimental Economics to Evaluate Consumer Preferences Methods in Consumer Research*, Woodhead Publishing, Cambridge, Vol. 1, pp. 583-607.

Velu, G., Rai, K., Muralidharan, V., Kulkarni, V., Longvah, T. and Raveendran, T. (2007), "Prospects of breeding biofortified pearl millet with high grain iron and zinc content", *Plant Breeding*, Vol. 126 No. 2, pp. 182-185.

Vickrey, W. (1961), "Counterspeculation, auctions and competitive sealed tenders", *Journal of Finance*, Vol. 16 No. 1, pp. 8-37.

West, S.G., Biesanz, J.C. and Kwok, O.-M. (2004), *Within-Subject and Longitudinal Experiments: Design and Analysis Issues*, Sage Publications, New York, NY.

Appendix 1
Questionnaire: Part A

Ragi Auction Questionnaire	Your information will be held <u>anonymously</u> and will be <u>only used for scientific purposes.</u>	ID: 1011

Part A: First part of the questionnaire

A.1 Where do you live (location of your family household)? *(Please write down the name of the district and the name of the taluk on the lines provided.)*	
Name of district:	----------
Name of taluk:	----------

A.2 Do you live in an urban, semi/peri-urban or rural area (location of your family household)? *(Please tick ONE box only.)*	
Urban area	☐
Semi/peri-urban area	☐
Rural area	☐

A.3 What is your age? *(Please fill in the box provided.)*	
Age:	

A.4 What is your gender? *(Please tick ONE box only.)*	
Male	☐
Female	☐

A.5 How many years of education have you completed? *(Please tick ONE box only.)*	
None	☐
1 to 5 years	☐
6 to 10 years	☐
11 to 12 years	☐
13 to 15 years	☐
More than 15 years	☐

A.6 Can you converse in English? *(Please tick ONE box only.)*	
Yes, fluent.	☐
Yes, a little.	☐
No.	☐

A.7 Are you currently married? *(Please tick ONE box only.)*	
Yes	☐
No	☐
No answer	☐

A.8 What is your religion? *(Please tick ONE box only.)*	
Hindu	☐
Muslim	☐
Christian	☐
Buddhist	☐
Other	☐
None	☐
No answer	☐

A.9 How many people live in your family household, including you? *(Please fill in the box provided)*	
Number of people:	

A.10 Is there children below the age of 5 living in your family household? *(Please tick ONE box only.)*	
Yes	☐
No	☐

A.11 Is anyone in your household expecting a baby? *(Please tick ONE box only.)*	
Yes, I am.	☐
Yes, someone else is.	☐
No, as far as I know no one.	☐
No answer	☐

A.12 What is the monthly income of your family household? *(Please tick ONE box only.)*	
No (regular) income	☐
Less than Rs. 10’000	☐
Rs. 10’000 – 20’000	☐
Rs. 20’001 – 30’000	☐
Rs. 30’001 – 40’000	☐
More than Rs. 40’000	☐
No answer	☐

A.13 Does your household have a ration card? *(Please tick ONE box only.)*		
If yes:		
	Anthodaya anna Yojana card.	☐
	Below poverty line.	☐
	Above poverty line.	☐
No		☐

A.14 What is the PRINCIPAL source of income for your household? *(Please tick ONE box only.)*	
Crop cultivation	☐
Allied agriculture	☐
Agricultural wage labor	☐
Non agricultural wage labor	☐
Artisan/ independent work	☐
Petty shop/ other trade	☐
Organized trade/ business	☐
Salaried employment	☐
Pension/ rent/ dividend, etc.	☐
Other	☐

A.15 Did your household grow ragi in the last 12 months? *(Please tick ONE box only.)*	
Yes	☐
No	☐

A.16 Does your household own any of the following goods? *(Please tick all the goods your household owns.)*	
Computer	☐
Car	☐
Motorbike	☐
TV	☐
None of the above	☐

A.17 Are you responsible OR at least jointly responsible for the food purchase in your family household? *(Please tick ONE box only.)*	
I am the only one responsible for food purchase.	☐
I am jointly responsible for food purchase.	☐
No, I am NOT responsible for food purchase.	☐

A.18 How much of the following items have been CONSUMED by your household in the past 30 days? *(Please fill in the boxes provided)*	
Ragi:	☐ kilograms
Rice:	☐ kilograms
Wheat:	☐ kilograms

A.19 How much of the following items did your household BUY in the past 30 days?
(Please fill in the boxes provided)

	From shops (in kilograms)	From public distribution system (in kilograms)
Ragi:	☐	☐
Rice:	☐	☐

Wheat:		

A.20 Imagine you find the following claim on a food product: “This food is high in iron”. What does this mean? *(Please tick the box that you think is correct)*	
It means, that the food has a specific taste, because iron is a spice.	☐
It means, that the food is healthy, because iron is an important nutrient for the human body.	☐
It means, that the food can be unhealthy, if consumed in large quantities.	☐
I don’t know.	☐

Appendix 2
Questionnaire: Part B

Ragi Auction Questionnaire	Your information will be held anonymously and will be only used for scientific purposes. — ID: 1011

Part B: Second part of the questionnaire

B.1 Do you know why the consumption of iron is important? *(Please tick the box that you think is correct)*	
Yes, because it protects pregnant women from having a baby with a birth defect.	☐
Yes, because it is necessary for a good vision.	☐
Yes, because it makes us feel less tired and strengthens our immune system.	☐

B.2 Have you ever taken iron pills/ supplements? *(Please tick ONE box only.)*		
If yes:		
	Currently taking.	☐
	Taken in the past, but not anymore.	☐
No.		☐

B.3 Has any other household member ever taken iron pills/ supplements? *(Please tick ONE box only.)*		
If yes:		
	Currently taking.	☐
	Taken in the past, but not anymore.	☐
No.		☐
I don't know.		☐

B.4 Have you ever suffered from an iron deficiency or anaemia? *(Please tick ONE box only.)*		
If yes:		
	Currently suffering.	☐
	Suffered in the past, but not anymore.	☐
No.		☐
I don’t know.		☐

B.5 Has any other household member ever suffered from an iron deficiency or anaemia? *(Please tick ONE box only.)*		
If yes:		
	Currently suffering.	☐
	Suffered in the past, but not anymore.	☐
No.		☐
I don’t know.		☐

Appendix 3
Questionnaire: Part C

Ragi Auction Questionnaire	Your information will be held anonymously and will be only used for scientific purposes.	ID: 1011

Part C: Third part of the questionnaire

C.1 How do you think high-iron ragi has been made? *(Please tick the box that you think is correct)*	
High-iron ragi has probably been made using genetic modification.	☐
They probably just added iron to the ragi grains.	☐
They probably used some modern breeding technologies.	☐
I don't know.	☐

C.2 Are you generally sceptical towards newly developed crop varieties, be it ragi, rice or another crop? *(Please tick ONE box only.)*	
Yes, very sceptical.	☐
Yes, rather sceptical.	☐
No, rather not sceptical.	☐
No, not sceptical at all.	☐

Appendix 4
The supplementary material is available online for this article.

Corresponding author
Claudia Meier can be contacted at: claudia.meier@fibl.org