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**Tanzanian Willingness-to-Pay for Rice that Decreases
the Risk of Severe Visual Impairment**

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1. Introduction

Although availability of nutritious food is a problem globally, citizens of developing countries are more likely to be affected by undernourishment. Currently, more than 220 million people in Sub-Saharan African (SSA) are undernourished (FAO, 2015). Undernourishment is the cause of many diseases, and even death, for many young children and women. Beyond the pervasive health implications, undernourishment also negatively affects socio and economic progress at both an individual and national level (Khush, Lee, Cho, & Jeon, 2012), which creates a cycle of poverty and disease.

The risk of malnutrition, arising from undernourishment, is striking for young children and pregnant or lactating women. In 2011, an estimate of 40% of childhood below five years had chronic malnutrition in SSA (Marx et al., 2014). Similar to many other SSA countries, the Tanzanian population is burdened by malnutrition. Despite declining rates of malnutrition in Tanzania, the prevalence of malnutrition in children under the age of five is approximately 36%, and mortality from malnutrition is approximately 28% (Ngallaba et al., 2014).

Vitamin A can be sourced from both plant and animal foods. Plants such as carrots, squash, pumpkin, and sweet potatoes are great sources of precursors to vitamin A. These plants are rich in beta-carotene, a precursor to vitamin A, which the human body converts into vitamin A. Animal products like egg yolk, fish, liver, and dairy are direct sources of vitamin A. When properly consumed, these foods can provide the best solution for micronutrient deficiencies. Sufficient intake of vitamin A helps vision (reduces the risk of blindness and night blindness), regulates immune function, and aids growth development (Tang, Qin, Dolnikowski, Russell, & Grusak, 2009).

Micronutrient malnutrition, also called hidden hunger, is the chronic lack of critical vitamins, like vitamin A. The effects of vitamin A deficiency (VAD) are not trivial. The effects of VAD include severe visual impairment (e.g., blindness and night blindness) and severe illnesses and diseases that sometimes cause mortality. VAD mostly affects children under five years of age and women. Women in developing countries are VAD because of prolonged breast feeding combined with diets low in vitamin A and precursors to vitamin A, which the body converts to vitamin A (Miller et al., 2002). Subsequently, children become vitamin A deficient in early ages from consuming breast milk and foods which are low in vitamin A and precursors

to vitamin A. In 2010, for example, the Tanzania National Bureau of Statistics reported about 33% of children under the age of five and 36% of women were VAD.

A number of interventions have been taken by to alleviate the increasing problems related to VAD. Interventions include nutritional education programs, supplementation through vitamin A capsules and drops, and fortification of staple foods. Unfortunately, the interventions do not always reach the most vulnerable groups. This is especially true in Tanzania, where public spending on nutrition is not effectively targeted to young children and pregnant women (Picanyol et al., 2015). Moreover, the costs associated with administering supplementation programs are relatively high (Fiedler et al., 2000; Zimmermann & Qaim, 2004). Even when the costs of supplementation may be economically feasible, the distribution costs are usually higher than what is affordable (Dawe, Robertson, and Unnevehr, 2002).

Fortification has the possibility to be an efficient and cost-effective strategy to address micronutrient malnutrition because it improves the nutrition profile of staple foods that low income and rural populations commonly consume (Beyer, 2010; Khush et al., 2012; Kimenju & De Groote, 2008). Unlike regular rice, biofortified rice has added nutritional value that may decrease diseases caused by micronutrient deficiencies. Although biofortification is not a panacea for micronutrient deficiency, it can be used to complement the existing interventions (Dawe et al., 2002). Biofortification can be accomplished through both conventional breeding techniques and genetic modification (GM).

Golden rice (GR) is a rice variety that has been genetically modified to increase beta carotene, a precursor to vitamin A. The accumulation of beta-carotene gives the rice a yellow or golden color when milled, hence the name GR (Schaub, 2005). Since rice that is not biofortified does not contain beta-carotene, many people in low income countries with a diet comprised mostly of rice suffer from VAD. Increasing death rate, blindness and other diseases due to VAD necessitated the need for GR as an alternative strategy to reduce the effects of VAD among poor populations in developing countries (Albabili & Beyer, 2005; Anderson, Jackson, & Nielsen, 2005; Dawe et al., 2002; D. Dawe & Unnevehr, 2008).

No research, that we are aware of, has been conducted to determine perceived risk of VAD in developing areas. While GR may be a viable strategy for decreasing VAD, it is not

clear how consumers in developing areas will respond to the technology and color associated with GR. Previous research has examined willingness-to-pay (WTP) for GR in developing areas (Alphonse & Alfnes, 2012; Mwaijande, Tsiboe, Durand-Morat, & Wailes, n.d; Corrigan et al., 2009; Depositario et al., 2009), however, these studies used GM as the attribute to infer WTP for GR. In the U.S., where consumers have been exposed to the concept of GM for some time, consumers remain unknowledgeable about the implications of GM. Moreover, while consumers in the U.S. are generally averse to GM food, consumers desire some of the outcomes associated with GM, particularly if the outcome of the GM is beneficial to consumers (Lusk et al., 2005; Lusk, McFadden, and Rickard, 2015).

There is a need to better understand the perceived risk of VAD and severe visual impairment. Furthermore, there is a need to better understand awareness of biofortification as a remedy for VAD and WTP for rice that could decrease the risk of severe visual impairment. The objectives of this study were to: 1) gain a better understanding of the perceived risk of VAD and severe visual impairment; 2) gain a better understanding about the awareness of biofortification; and 3) determine WTP for rice that could decrease the risk of severe visual impairment.

2. Methods

2.1 Survey Design

The survey was designed using Qualtrics®. After consenting to complete the survey, respondents were asked questions that measured willingness-to-pay (WTP) for rice. There were three blocks of questions that measured WTP for rice, which are described in more detail in subsequent subsections. Two blocks consisted of contingent valuation (CV) questions that used the double-bounded dichotomous-choice (DBDC) format to elicit WTP. One CV block elicited WTP for rice that decreased the risk of severe visual impairment, and the other CV block elicited WTP for rice biofortified to increase the level of vitamin A. The third block consisted of a conjoint analysis (CA) that elicited WTP for various rice attributes (i.e., night blindness, color, length, and price). The order of the blocks were randomized across respondents to minimize any order effects.

After the three blocks of questions that measured WTP for rice, respondents answered a series of questions that determined perceived risk of VAD and severe vision impairment (i.e., blindness and night blindness). The respondents then answered questions that determined knowledge of biofortified and GM crops. The respondents finished the survey by answering demographic questions.

2.2 Contingent Valuation Questions and Double-Bounded Dichotomous-Choice Models

There were two CV question blocks that elicited WTP for rice. One CV block elicited WTP for rice that decreased the risk of severe visual impairment, and the other CV block elicited WTP for rice biofortified to increase the level of vitamin A. In the CV block elicited WTP for rice biofortified to increase the level of vitamin A, respondents chose between a rice option that was biofortified to increase the level of vitamin A, and a rice option that was not biofortified. Respondents repeated this process but biofortified was replaced with GM, the specific method of biofortification for GR. In the CV block elicited WTP for rice that decreased the risk of severe visual impairment, respondents chose between a rice option that decreased the risk of blindness and night blindness by half, and a rice option that did not decrease the risk of blindness and night blindness. Respondents repeated this process for a rice option that completely decreased the risk of blindness and night blindness.

Both CV blocks followed the DBDC format discussed in Hanemann, Loomis, and Kanninen (1991). The DBDC format is commonly used in CV questions because it provides more efficient estimates than the single-bound format. Moreover, conducting WTP studies in developing areas is challenging and DBDC demand less explanation because purchase prices are predetermined (Durand-Morat, Wailes, and Nayga, 2015). In each CV block, two sets of DBDC questions were asked.

The DBDC format differs from a single-bound dichotomous-choice format by asking a follow-up dichotomous-choice question. For example, respondents who chose the GM rice option were then asked the dichotomous-choice question again, however, the price for the GM rice was increased to <<Higher Price>>. <<Higher Price>> varied randomly across respondents from Tsh 2000 to Tsh 2400 with a mean of Tsh 2206. Conversely, respondents who did not

choose the GM rice option were then asked the dichotomous-choice question again, however, the price for the GM rice was decreased to $\llcorner\llcorner Lower Price\gg\gg$. $\llcorner\llcorner Lower Price\gg\gg$ varied randomly across respondents from Tsh 1200 to Tsh 1600 with a mean of Tsh 1794. A similar process was replicated for the other sets of DBDC CV questions.

Accordingly, there were four possible outcomes for a set of DBDC questions. For illustration, we will continue with the GM question shown in Figure 1. The four possible outcomes were: 1) yes to GM at Tsh 1800, and yes to GM at $\llcorner\llcorner Higher Price\gg\gg$; 2) yes to GM at Tsh 1800, and no to GM at $\llcorner\llcorner Higher Price\gg\gg$; 3) no to GM at Tsh 1800, and yes to GM at $\llcorner\llcorner Lower Price\gg\gg$; 4) no to GM at Tsh 1800, and no to GM at $\llcorner\llcorner Lower Price\gg\gg$. Following the approach of Hanemann, Loomis, and Kanninen (1991), the probabilities for “YES, YES” ($\pi_i^{YES,YES}$); “YES, NO” ($\pi_i^{YES,NO}$); “NO, YES” ($\pi_i^{NO,YES}$); and “NO, NO” ($\pi_i^{NO,NO}$) responses for the i^{th} respondent is given by:

$$(1) \quad \pi_i^{YES,YES} = \text{Prob}\{WTP_i \geq Higher Price_i\} = \Phi(Higher Price_i; \boldsymbol{\beta}, \gamma),$$

$$(2) \quad \pi_i^{YES,NO} = \text{Prob}\{1800 \leq WTP_i \leq Higher Price_i\} = \Phi(1800; \boldsymbol{\beta}, \gamma) - \Phi(Higher Price_i; \boldsymbol{\beta}, \gamma),$$

$$(3) \quad \pi_i^{NO,YES} = \text{Prob}\{Lower Price_i \leq WTP_i \leq 1800_i\} = \Phi(Lower Price_i; \boldsymbol{\beta}, \gamma) - \Phi(1800; \boldsymbol{\beta}, \gamma),$$

$$(4) \quad \pi_i^{NO,NO} = \text{Prob}\{WTP_i \leq Lower Price_i\} = 1 - \Phi(Lower Price_i; \boldsymbol{\beta}_{V2}, \gamma),$$

where WTP_i is the true unobserved WTP for respondent i , $Higher Price_i$ and $Lower Price_i$ are the changes in price random assigned to respondent i , $\boldsymbol{\beta}$ is a vector of coefficients to be estimated for explanatory variables in vector \mathbf{X} , and γ is an additional coefficient to be estimated for $Price$. The coefficients are estimated using maximum likelihood where the log likelihood function is:

$$(5) \quad \ln L(\boldsymbol{\beta}, \gamma) = \sum_{i=1}^{300} \{ I_i^{YES,YES} [\Phi(Higher Price_i; \boldsymbol{\beta}, \gamma)] + I_i^{YES,NO} [\Phi(1800; \boldsymbol{\beta}, \gamma) - \Phi(Higher Price_i; \boldsymbol{\beta}, \gamma)] + I_i^{NO,YES} [\Phi(Lower Price_i; \boldsymbol{\beta}, \gamma) - \Phi(1800; \boldsymbol{\beta}, \gamma)] + I_i^{NO,NO} [1 - \Phi(Lower Price_i; \boldsymbol{\beta}_{V2}, \gamma)] \},$$

where $I_i^{YES,YES}$; $I_i^{YES,NO}$; $I_i^{NO,YES} = 1$; or $I_i^{NO,NO} = 1$; if respondent i responded “YES, YES”; “YES, NO”; “NO, YES”; or “NO, NO” to a DBDC question, respectively.

Perceived risk of VAD and severe vision impairment (i.e., blindness and night blindness), as well as demographic variables (i.e., age, gender, household size, and income) were included as explanatory variables in vector \mathbf{X} . Mean WTP for rice was calculated using the means for the explanatory variables and the coefficients from the estimated model. Specifically, mean WTP was calculated by:

$$(6) \quad WTP^{mean} = -\frac{\bar{\mathbf{X}}'\boldsymbol{\beta}}{\gamma}.$$

Mean WTP was calculated for the four sets of DBDC question asked.

2.3 Conjoint Analysis and Model

In the CA, respondents made choices between two rice options, or a no purchase option. The two rice options varied by four attributes, and each attribute was varied at three levels. The attributes included vision benefit (does not decrease the risk of blindness or night blindness, decreases the risk of both blindness and night blindness by half, completely eliminates the risk of both blindness and night blindness), color (brown, yellow, white), length (short, medium, long), and price (1600 Tsh, 1800 Tsh, 2000 Tsh). A main-effects only, orthogonal fractional factorial design was implemented and resulted in a total of 27 choices sets for the CA. An example of a choice set for the CA is shown in Figure 2.

To analyze the CA data, a random utility model, pioneered by McFadden (1974), was utilized. Assume respondent i derives the following utility for rice option j : $U_{ij} = V_{ij} + \varepsilon_{ij}$, where V_{ij} is the deterministic and ε_{ij} is the stochastic portion of utility. The systematic portion of the utility of option j for respondent i is defined as:

$$(7) \quad V_{ij} = \alpha_1 \text{Vision Benefit}_j + \alpha_2 \text{Color}_j + \alpha_3 \text{Length}_j + \alpha_4 \text{Price}_j.$$

If faced with J choice options, a respondent is assumed to choose option j if $U_{ij} > U_{il}$ for all $j \neq l$. If the ε_{ij} are distributed iid extreme value, then the probability of individual i choosing option j is

$$(2) \quad \text{Prob}(\text{option } j \text{ is chosen}) = \frac{e^{V_{ij}}}{\sum_{k=1}^J e^{V_{ik}}},$$

which is the well-known multinomial logit model.

2.4 Respondents

The study was conducted in Morogoro region in Tanzania during the months of September and October 2015. Data were collected from a random sample of 300 households in two districts, Morogoro urban and Mvomero. Each district was randomly divided into nine sub-locations. There were nine villages in Mvomero and nine wards in Morogoro urban. From each sub-location, an average of 17 households were randomly selected to make a total of 150 households for each district. The two districts were purposely selected because they are easily reachable and there are many rice consumers.

Respondents were members of the household who make purchasing decisions for the family. Though randomly selected, the proportion of female respondents was relatively higher than male respondents because female respondents were more likely to purchase food for a family. The selected households were interviewed through face to face interview using a structured questionnaire. Informed consent policy was adhered to all respondents prior to the interview. Each respondent was compensated with 5,000 Tsh (approximately 2.5 USD).

Table 1 presents a summary statistics of the socio-demographic variables. There was an approximately equal representation of respondents living in rural areas of Mvomero district (51%) and Morogoro Urban (49%). Female respondents constitutes more than 60% of respondents. This was important because women make most of the purchasing decisions, especially food items. Marital status shows that about 74% of all the respondent are married couples. The majority of respondents had low a level of education. About 11% of the respondents did not complete formal education, 63% completed primary school, while less than 10% of respondents had some college or university education. Seventy-six percent of respondents were self-employed, mostly in agriculture and small businesses. More than one half of the respondents were between the ages of 18 and 39 years. On average, the size of the family is considerably large, with 62% of respondents having 4 to 7 people living in a household.

Twenty-six percent of respondents have a combined monthly household income below 50,000 Tanzanian shillings (Tsh), 28 % had an income between Tsh 100,001 to 250,000, and only 4% of respondents are able to earn between Tsh 500,001 to 1,000,000 per month.

3. Results

3.1 Perceived Risk of VAD and Severe Visual Impairment and Awareness of Biofortified Crops

The perceived risk of being VAD and becoming blind are shown in Figure 3. As shown, almost half of respondents (125 or 41.7%) chose the “I do not know” perceived risk category for being VAD. The number of “I do not know” responses were much lower for becoming blind (19 or 6.3%) and night blind (30 or 10%). The perceived risk category chosen the most for both becoming blind and night blind was “Medium Risk,” this was also true for being VAD if you exclude the “I do not know” category. Perceived risk was greater for becoming night blind than becoming completely blind or being VAD.

Only a small portion of respondents were aware of biofortification. Eighteen percent of respondents indicated they had heard of biofortified crops, and 20% indicated they had heard of GM crops. Of the 20% of respondents that indicated they had heard of GM crops, 34% indicated that GM crops were good, 36% did not know if GM crops were good, and 30% indicated that GM crops were not good.

3.2 WTP for Rice that could Decrease the Risk of Severe Visual Impairment

Figure 2 shows the responses for the DBDC CV questions. Most all respondents chose the rice option that decreased the risk of severe visual impairment or had an increased level of vitamin A for the first question. After a viewing a higher price in the follow-up question, the majority of respondents continued to choose the rice options that decreased the risk of severe visual impairment or had an increased level of vitamin A.

Coefficient estimates from the maximum likelihood estimations for the DBDC CV questions are shown in Table 2. *Price* was significant and negative for all models. *Age* was significant and negative for both models in the CV block that elicited WTP for rice that

decreased the risk of severe visual impairment. This indicates that younger respondents were WTP more for rice that reduces the risk of severe visual impairment, and may indicate that younger consumers are more concerned about blindness and night blindness.

Mean WTP for a Kg of rice that decreased the risk of severe visual impairment by half was Tsh 2264, while mean WTP for a Kg of rice that completely decreased the risk of severe visual impairment was Tsh 2266. Mean WTP for a Kg of rice that had an increased the level of vitamin A from biofortification and GM was Tsh 2271 and Tsh 2316, respectively. On average, respondents indicated that they typically spent Tsh 1711 (standard deviation = Tsh 167) for a Kg of rice. Thus, respondents were WTP a premium for rice that decreased the risk of severe visual impairment or had an increased level of vitamin A.

Coefficient estimates from multinomial logit estimations for the CA are shown in Table 3. All coefficient estimates were significant. Respondents preferred rice that decreased the risk of severe visual impairment, was white in color, and longer grain length. On average, respondents were WTP a premium of Tsh 894 for rice that decreased the risk of severe visual impairment by half and Tsh 1398 for rice that completely eliminated the risk. However, these premiums decreased after accounting for the yellow color of GR to Tsh 451 and Tsh 956, respectively.

4. Conclusions

In this study contingent valuation and conjoint analysis methods were used to elicit Tanzanian consumer's WTP for rice that benefits vision. Using data from a survey of 300 rice consumers in Morogoro region, the findings conclude that Tanzanians are concerned about vision problems and vitamin A deficiency, though it is not clear everyone understands that vitamin A deficiency causes vision problems. In our analysis, we also found that most respondents have low level of awareness of biofortification and GM technologies. However, low level of awareness and knowledge does not necessarily mean that they are averse to these technologies. Based on the results of this study, Tanzanian consumers strongly prefer and are willing to pay for rice with added nutritional value.

It is not possible to know why the "I do not know" responses were so much higher for being VAD. However, it is likely much of the sample was not aware of what it means to be

VAD. If that is the case, then there is a need to communicate what it means to be VAD and the consequences. However, the perceived risk category “Very Serious Risk” was chosen more for being VAD than becoming blind or night blind, which may indicate the perceived risk is greater for those respondents who know what being VAD meant.

There were limitations to this study. The survey was only conducted in two districts of Morogoro region. Awareness and WTP results for the respondents may not be the same for other districts. The use of conjoint analysis to estimate WTP for different rice attributes may also have its limitations. Rice attributes and its levels included in the study might not be enough to reflect the exact preference and WTP. It is likely that there are other rice attributes that are important but have been excluded in this study. Additionally, the study did not have enough respondents who have attained higher levels of education. Most respondents had low levels of education. This demographic variable and others are important to explain the structural changes in terms of awareness, preference for rice attributes and WTP. Further studies could focus on involving more attributes and using larger and more diverse sample size.

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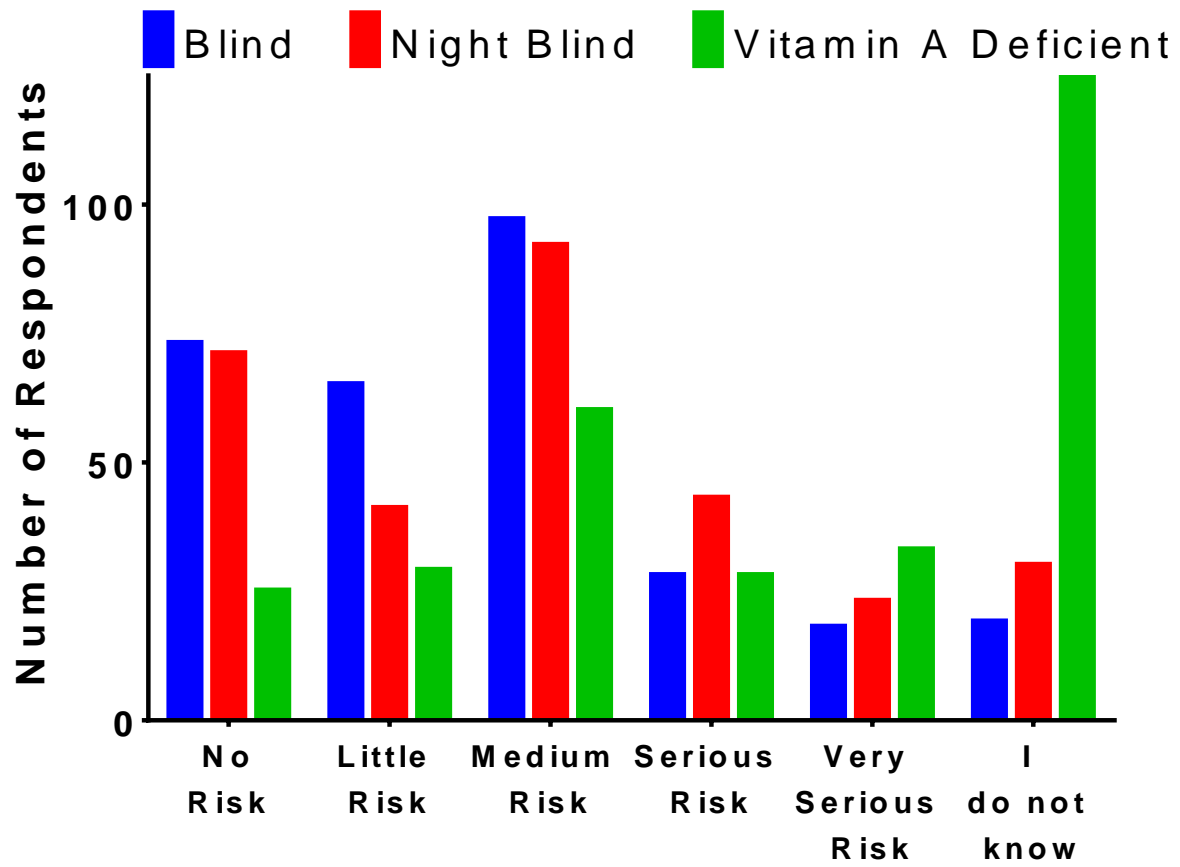


Figure 1. Perceived Risk of VAD and Severe Visual Impairment

	Decrease risk of severe visual impairment by half		Completely decreases the risk of severe visual impairment		Genetically modified to increase the level of Vitamin A		Bio-fortified to increase the level of Vitamin A	
1st Question	YES	NO	YES	NO	YES	NO	YES	NO
Number of Respondents	295	5	295	5	280	20	288	12
2nd Question	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO	YES NO
Number of Respondents	175 120	3 2	176 119	2 3	173 107	4 16	164 124	2 10
Average Price (Tsh)	2163 2254	1451 1349	2160 2240	1427 1320	2179 2248	1401 1433	2177 2245	1479 1384

Figure 2. Responses to Double-Bounded Dichotomous-Choice Contingent Valuations

Table 1. Summary Statistics of Respondents (n=300)

Variable	Category	Frequency	Relative Percent
<i>Geographic location</i>	Morogoro urban	146	48.7
	Mvomero district	154	51.3
<i>Gender</i>	Male	114	38
	Female	186	62
<i>Age category</i>	18 to 29 years	80	26.7
	30 to 39 years	90	30
	40 to 49 years	57	19
	50 to 59 years	49	16.3
	60 years and above	24	8
<i>Level of Education</i>	No school completed	34	11.3
	Primary school	189	63
	Secondary school	57	19
	Diploma/Certificate	15	5
	Bachelor's degree	4	1.3
	Master's degree	1	0.3
<i>Employment status</i>	Employed for wages	21	7
	Self employed	236	78.7
	Out of work (retired)	15	5
	Out of work (seeking)	6	2
	Other	22	7.3
<i>Number of people in a household</i>	0-3	94	31.3
	4-7	185	61.7
	8 and more	21	7
<i>Monthly household income</i>	Below 50,000	77	25.7
	50,001 to 100,000	68	22.7
	100,001 to 250,000	85	28.3
	250,001 to 500,000	59	19.7
	500,001 to 1,000,000	11	3.7
<i>Marital status</i>	Married	221	73.7
	Widowed	26	8.7
	Single, never married	30	10
	Separated	23	7.7

Table 2. Coefficient Estimates for Double-Bounded Dichotomous-Choice Contingent Valuations

Independent Variables	Contingent Valuation Questions for Rice			
	<i>Reduces risk of severe visual impairment by half</i>	<i>Completely reduces risk of severe visual impairment</i>	<i>GM to increase the level of vitamin A</i>	<i>Biofortified to increase the level of vitamin A</i>
Constant	8.920* (0.811)	8.547* (0.759)	4.664* (0.535)	5.646* (0.570)
<i>Blind Risk Perception</i>	-0.018 (0.114)	0.189 (0.115)	0.089 (0.110)	0.043 (0.108)
<i>Night Blind Risk Perception</i>	0.125 (0.110)	-0.048 (0.110)	0.118 (0.105)	0.078 (0.103)
<i>Vitamin A Def Risk Perception</i>	0.142 (0.097)	0.153 (0.096)	0.098 (0.090)	0.172 (0.090)
<i>Age</i>	-0.140** (0.067)	-0.190* (0.069)	0.002 (0.064)	-0.002 (0.065)
<i>Female</i>	-0.116 (0.160)	-0.227 (0.159)	-0.132 (0.149)	-0.062 (0.150)
<i>Household Size</i>	-0.029 (0.043)	0.004 (0.043)	0.008 (0.041)	-0.009 (0.041)
<i>Income</i>	0.122 (0.064)	0.137** (0.064)	0.090 (0.060)	0.098 (0.060)
<i>Price</i>	-0.004* (0.000)	-0.004* (0.000)	-0.002* (0.000)	-0.003* (0.000)
Log Likelihood	-412.8	-427.9	-542.4	-259.90

Note: Estimates are from maximum likelihood estimation using 300 observations. Standard errors are reported in parenthesis. * and ** represent 0.01 and 0.05 levels of statistical significance, respectively.

Table 3. Coefficient Estimates for Conjoint Analysis

Variable	Level	Coefficient
Constant		5.172* (0.283)
Vision Benefit	<i>Decrease risk of blindness by half</i>	2.708* (0.071)
	<i>Completely decrease risk of blindness</i>	4.237* (0.080)
Color	<i>Brown</i>	-1.187* (0.058)
	<i>Yellow</i>	-1.340* (0.070)
Length	<i>Medium</i>	0.900* (0.059)
	<i>Long</i>	1.087* (0.056)
Price	<i>Tsh/Kg</i>	-0.003* (0.000)

Note: Estimates are from maximum likelihood estimation using 8,100 observations (300 respondents x 27 questions). Log Likelihood = -4134.001. Standard errors are reported in parenthesis. * represent 0.01 level of statistical significance.