Consumer Acceptance of Second Generation GM Foods: The Case of Biofortified Cassava in the Northeast of Brazil

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Abstract

Biofortified staple foods are currently being developed to reduce problems of micronutrient malnutrition among the poor. This partly involves use of genetic modification. Yet, relatively little is known about consumer acceptance of such second generation genetically modified (GM) foods in developing countries. Here, we analyze consumer attitudes towards provitamin A GM cassava in the northeast of Brazil. Based on stated preference data, mean willingness to pay is estimated at 60-70% above market prices for traditional cassava. This is higher than results from similar studies in developed countries, which is plausible given that micronutrient malnutrition is more severe in developing countries. GM foods with enhanced nutritive attributes seem to be well received by poor consumers. But the results also suggest that acceptance would be higher still if provitamin A were introduced to cassava through conventional breeding. Some policy implications are discussed.

Keywords: choice modelling; contingent valuation; GM food; vitamin A; willingness to pay; Brazil; consumer behaviour

JEL classifications: *D12*, *O32*, *O33*, *Q16*.

1. Introduction

Micronutrient malnutrition is a widespread and serious problem, especially in developing countries, resulting in high economic and human costs (WHO, 2008; FAO, 2004). This is primarily the result of insufficient vitamin and mineral intakes among the poor, whose diets are

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often dominated by starchy staple foods. Due to their higher physiological requirements, women and children are the most affected. Health consequences of micronutrient deficiencies can be severe – including physical and mental impairment, higher susceptibility to infectious diseases, and premature death (UN-SCN, 2004). Clinical levels of vitamin A deficiency can also lead to blindness.

Interventions to reduce the problem include food supplementation and industrial fortification programs, but their effectiveness remains limited, mostly due to difficulties in reaching the target populations in rural areas (Allen, 2003). More recently, biofortification – i.e., breeding staple crops for higher micronutrient contents – has been proposed (Nestel *et al.*, 2006). Preliminary analyses suggest that this could be a cost-effective complementary strategy to address micronutrient malnutrition in developing countries (Qaim *et al.,* 2007). However, most biofortified crops are still in the research pipeline, so that relatively little is known about their actual implications.

In the HarvestPlus Challenge Program of the Consultative Group on International Agricultural Research, plant breeders are working on increasing iron, zinc, and provitamin A contents in different staple crops. Research under HarvestPlus mostly builds on conventional breeding techniques, exploiting the genetic variability within crop species. Yet there are also species where certain micronutrients are absent, or occur only in very small amounts, so that use of biotechnology seems more promising. A case in point is cassava, which contains provitamin A, but only at relatively low levels. Genetic modification could potentially boost provitamin A contents, thus more effectively reducing problems of vitamin A deficiency in cassava eating populations. On the other hand, genetically modified (GM) cassava might raise consumer concerns about health and environmental risks or potential ethical objections. Here, we analyze consumer acceptance of GM biofortified cassava in Brazil, using stated preference data collected

during a household survey in 2006. We focus on the northeast of the country, where nutritional deficiencies are particularly severe, and where cassava consumption is high.

Recently, several studies have been conducted on consumer attitudes towards GM crops. The majority deals with consumers in developed countries (e.g., Lusk *et al.*, 2006; Jan *et al.*, 2006; Kim and Boyd, 2004**;** McCluskey *et al.*, 2003), but the body of literature on developing countries is also growing (e.g., Kimenju and De Groote, 2008; Krishna and Qaim, 2008; Curtis *et al.,* 2004). In general, attitudes seem to be more positive in developing than in developed countries, which might be due to more widespread food insecurity among poor households and the recognition that new technologies could contribute to improving the situation. Nonetheless, many consumers claim that they would purchase GM food only at a price discount. It should be noted, though, that the studies mentioned relate to first generation GM crops, that is, crops with modified agronomic traits, which primarily lead to advantages in farm production. The situation might be different when GM crops entail direct benefits for consumers, such as nutrition and health advantages (Loureiro and Bugbee, 2005; Lusk *et al.*, 2005). A few recent studies have explicitly analyzed consumer attitudes towards such second-generation GM crops (e.g., Han and Harrison, 2006; Rousu *et al.*, 2005; Onyango and Nayga, 2004; Lusk, 2003), and, indeed, acceptance levels seem to rise, at least in developed countries. In developing countries, hardly any related research has been carried out so far. This is considered a knowledge gap, especially with respect to GM biofortified crops which offer solutions to widespread nutritional problems among the poor.

Our analysis of biofortified cassava in Brazil addresses this knowledge gap. We hypothesize that consumers would accept GM cassava with increased levels of provitamin A and would appreciate the nutritional benefits, especially when they are aware of vitamin A deficiency problems. We test this hypothesis by using contingent valuation techniques and estimating

consumers' willingness to pay (WTP). Furthermore, we are interested in understanding how consumers value different attributes of the end product. Since cassava with somewhat lower levels of provitamin A could also be bred conventionally, it is instructive to know whether or not acceptance levels would be higher if no GM techniques were used. And finally, we are interested in consumers' valuation of visual characteristics, since adding provitamin A changes the colour of cassava from white to yellow. The trade-offs between different cassava attributes will be examined with the help of a choice modelling approach. The results can be useful for better understanding the implications of biofortified crops in developing countries as well as designing and fine-tuning appropriate research and dissemination policies.

The rest of this article is structured as follows. In section 2, a brief overview of vitamin A deficiency in the northeast of Brazil and the potential role of biofortified cassava is given. Then, the methodologies are described in section 3, before the survey data and the estimation results are presented and discussed in sections 4 and 5, respectively. The last section concludes.

2. Vitamin A Deficiency in Brazil and Biofortified Cassava

Vitamin A deficiency (VAD) is a serious health problem in Brazil (Santos, 2002). According to the World Health Organization, Brazil is classified as a country with severe levels of sub-clinical deficiency (WHO, 2008), although clinical eye symptoms are rare and therefore not reported. Owing to higher than average poverty rates, the prevalence of VAD is particularly high in the northeast (NE) of the country. Over half of the children in NE Brazil, and a significant percentage of pregnant and lactating women suffer from sub-clinical VAD (Mora *et al.,* 1998). For many years, the government has been pursuing a vitamin A supplementation program targeted at children and pregnant and lactating women, but coverage rates are relatively low and erratic over

time. A program evaluation, conducted between 1994 and 2003, showed that coverage ranged from 28% to 73% of the total target population (Martins *et al.*, 2007).

How could biofortified cassava improve the situation? Globally, more than 70 million people obtain at least 500 kilocalories per day from cassava, and Brazil is one of the countries where consumption is relatively high. The crop is especially important in the NE, where 9.7 million tons are produced, and per capita consumption levels are around 46 kg per year. Other important staple foods include beans and rice. The provitamin A content in popular white cassava varieties is zero. Yellow varieties with low levels of provitamin A exist, but they are generally not preferred by consumers in the region, partly for lack of awareness, but also because they usually require longer cooking times (which are not related to the provitamin A content).

HarvestPlus researchers have managed to increase provitamin A contents in locally adapted varieties to around 9 µg per gram of fresh weight (http://www.harvestplus.org). One problem is that post-harvest and processing losses can be relatively high. Therefore, further increasing provitamin A contents would be desirable to generate a significant nutritional impact, but high levels will require use of GM techniques. The advantage of GM techniques is also that the provitamin A trait could more easily be incorporated into popular cassava varieties, which would change the colour but none of the other characteristics (including cooking time).

A recent study indicated that VAD in NE Brazil leads to an annual disease burden equivalent to 0.1% of gross national income, and that this burden could be reduced by 19% in a hypothetical biofortification scenario with cassava containing 20 µg of provitamin A (Meenakshi *et al.*, 2007). With GM techniques, varieties with even higher levels might be achieved. Yet their development and introduction will still take several years, also because GM products usually involve complex regulatory procedures.

Very little is known about consumer acceptance of GM food in Brazil, in spite of the fact that herbicide-resistant GM soybeans have been grown in the country for several years. The few available studies show mixed results, perhaps because they were carried out by specific interest groups. Guivant (2006) reports two studies – one carried out by Greenpeace and the other by Monsanto. The Greenpeace study claimed that in NE Brazil 74% of the population would prefer GM-free food, while the Monsanto study claimed that 80% would perceive GM crops as a possible way to improve the quality of life. There are other, more general and independent studies showing that attitudes towards modern science are quite positive in Brazil (Guivant, 2006). But none of these studies looked at second generation GM crops with enhanced nutritive attributes.

3. Methodology

We assess acceptance of biofortified cassava among consumers in NE Brazil by estimating their willingness to pay (WTP), based on a household survey specifically designed for this purpose. Our hypothesis of a generally positive attitude implies that consumers are willing to pay a premium for GM cassava with provitamin A. This does not mean that biofortified cassava will indeed be sold at a premium. The technology is being developed by the public sector with the aim to reduce malnutrition among the poor, so a low price will be sought to enable easy access. Hence, our WTP analysis should not be misinterpreted as an approach to develop a pricing strategy for a new commercial product. Rather, it as an analytical device to better understand technology acceptance levels and preferences among the target population.[2]

Different methodologies can be used to estimate consumer WTP. For products that are not yet available in the market, such as GM biofortified cassava, revealed preferences cannot be

[2] While WTP studies help to assess consumer acceptance in a quantitative way, it should be mentioned that other approaches, including qualitative ones, could also be used alternatively.

observed, so that stated preference data are generally used (e.g., Kimenju and De Groote, 2008; Onyango and Nayga, 2004; Lusk, 2003). We also use stated preference data in our context. Mostly, contingent valuation (CV) or choice modelling (CM) techniques are employed. Stated preference data are not without problems, however, as consumers respond to hypothetical scenarios, which often leads to overestimation of the true WTP (Diamond and Hausman, 1994).[3] Another common finding with respect to CV in particular is that estimation results can be quite sensitive to the study design (e.g., Christie and Azevedo, 2009). For instance, depending on the type of information provided and the question format used in the survey, there might be a yea-saying bias, that is, interviewees accepting to pay the specified amount to avoid the embarrassing social position of having to say no.

We have tried to reduce potential biases as much as possible through carefully designing and pre-testing the survey instruments and giving respondents a proper introduction to the study and its objectives. Furthermore, we use both CV and CM techniques, which helps to test for the robustness of the results.[4] Obtaining similar WTP estimates with different approaches is not a proof of correctness, but showing that the outcome is not strongly driven by the method used nonetheless increases reliability. Yet, it should be stressed that both CV and CM methods build on stated preference data, so that a hypothetical bias cannot be ruled out completely.

3.1 Contingent valuation

CV techniques are often used to analyze individual preferences and elicit the monetary value of goods that are non-marketable or not yet marketed. In a CV survey, questions can be asked in

[3] An alternative to stated preference data are experimental auctions carried out in the lab (e.g., Lusk *et al.*, 2006). Such lab experiments provide a good way to reduce the hypothetical bias, but the samples are usually smaller than in a survey and often confined to population sub-groups in one or few locations. Since our intention is to get a representative picture of different population groups' attitudes, stated preference data appear more appropriate in our context.

[4] See Bateman *et al.* (2006) for another recent study where CV and CM techniques were used and results compared.

different ways. We used a double-bounded dichotomous choice format, which is more efficient than single-bounded formats (cf. Bateman *et al.*, 2002, p. 285). Two sequential questions were posed to respondents: first, they were asked whether or not they would buy GM biofortified cassava at a certain randomly assigned price bid; then, second, a new random price bid was given, which – depending on the first answer – was either higher or lower than the initial bid. Answers to the sequential questions, and hence individual WTP values fall into one of the following four intervals $(-\infty, B_l)$, (B_l, B_i), (B_i, B_h), $(B_h, +\infty)$, where B_l, B_i, and B_h denote lower, initial, and higher price bid, respectively. The observable outcomes of the bidding process can be expressed as:

$$Y = \begin{cases} 1 & \text{if} \quad WTP < B_l \\ 2 & \text{if} \quad B_L \le WTP < B_i \\ 3 & \text{if} \quad B_i \le WTP < B_h \\ 4 & \text{if} \quad WTP \ge B_h \end{cases} \tag{1}$$

The WTP function is represented as:

$$WTP = \beta' x + \varepsilon \tag{2}$$

where x is the vector of explanatory variables such as consumer characteristics, β is a vector of unknown parameters to be estimated, and ε is a random error term with mean zero and variance σ^2. The parameters were estimated by maximizing the log-likelihood function of the outcomes in the bidding process:

$$\begin{aligned} \ln L = \sum \Bigg\{ & I_{Y=1} \ln\left[\Phi\left(\frac{B_l - \beta' x}{\sigma}\right)\right] + I_{Y=2} \ln\left[\Phi\left(\frac{B_i - \beta' x}{\sigma}\right) - \Phi\left(\frac{B_l - \beta' x}{\sigma}\right)\right] \\ & + I_{Y=3} \ln\left[\Phi\left(\frac{B_h - \beta' x}{\sigma}\right) - \Phi\left(\frac{B_i - \beta' x}{\sigma}\right)\right] + I_{Y=4} \ln\left[1 - \Phi\left(\frac{B_h - \beta' x}{\sigma}\right)\right] \Bigg\} \end{aligned} \tag{3}$$

where I_Y is a binary indicator variable for the four response groups. Division by σ in the coding of the log-likelihood function allows one to estimate β directly, so that the coefficients can be interpreted as the marginal effects of the x variables on WTP (Qaim and de Janvry, 2003). Accordingly, mean WTP is obtained as $E(WTP) = \hat{\beta}'\bar{x}$.

3.2 Choice modelling

CM is a tool to determine how consumers value different attributes of a certain good. The approach has been used recently for different GM derived foods (Jan *et al.*, 2007; Grunert *et al.*, 2004).[5] As with CV, CM can also produce WTP estimates for the good as a whole, with all its attributes, a fact that we exploit as a robustness check. In addition, the focus is on understanding WTP for individual attributes and the trade-offs involved. Since provitamin A biofortification – at least up to a certain level – is possible through both conventional and GM approaches, we are particularly interested in consumers' valuation of one versus the other breeding technique. Furthermore, we analyze colour preferences in cassava that also play a role in the biofortification context.

There are different possible formats for a CM study, including contingent ranking, contingent rating, and contingent choice. These techniques differ in the quality of information they generate, and also in their degree of complexity. The rating format makes very strong assumptions about human cognitive abilities (Louviere *et al.*, 2000, p. 30), and empirically rating data have been shown to deliver unstable and partly implausible WTP estimates (Calfee *et al.*, 2001). Among the other two formats, we prefer contingent ranking, as it provides more statistical

[5] Breustedt *et al.* (2008) have used data from a choice experiment with farmers to determine how different technology attributes influence their willingness to adopt GM crops.

information than contingent choice data. When the status quo is included as an option in the experiment, contingent ranking can produce welfare theory consistent estimates (Merino, 2003).

In the survey, respondents were asked to rank a set of cassava varieties that differed in terms of various attributes. For individual *i* let there be a choice set *C* with *J* elements and each element indexed *j* = 1, 2, …*J*. Let the vector of attributes for each element be denoted z_{ij}. The utility of each element in *C* for each individual is represented as:

$$U_{ij} = V_{ij}\left(z_{ij}\right) + \varepsilon_{ij}, \tag{4}$$

where V_{ij} is the deterministic component of utility, and ε_{ij} is the stochastic component. Let individual *i* generate a survey response $r_i = \left(r_{i1}, r_{i2}, ..., r_{iJ}\right)$, i.e., a ranking of the choice set in descending order of preference. The probability of a given survey response may then be expressed as:

$$\text{Prob}\left[U_i(r_{i1}) > U_i(r_{i2}) > ...U_i(r_{iJ})\right] \tag{5}$$

Assuming that V_{ij} is linear in parameters, the utility function can be written as $V_{ij} = \gamma' z_{ij}$. In principle, the parameters γ could be estimated with an ordered probit or logit model. However, Calfee *et al.* (2001) argued that rank-ordered logit models can lead to more reliable estimates. The difference between these models lies in the underlying assumptions about utility intervals. The ordered probit implicitly assumes that all respondents perceive approximately the same utility differences between alternatives. The rank-ordered logit, in turn, is a purely ordinal model that makes no assumptions about utility intervals. Technically, it makes full use of all ranking information by repeatedly applying a multinomial logit model that considers the ranked choices against the lower ranked-alternatives. For a given choice set, all the lower-ranked alternatives simply provide lower utility than the highest-ranked element, without a specific

(cardinal) difference (Calfee *et al.*, 2001). The probability that a given rank ordering will be observed has the closed-form solution:

$$\text{Prob}\,[U(r_1) > U(r_2) > .... > U(r_j)] = \prod_{h=1}^{J-1} \frac{e^{\gamma' z(r_h)}}{\sum_{m=h}^{J} e^{\gamma' z(r_m)}} \qquad (6)$$

where $z(r_h)$ is the vector of attributes of the alternative ranked *h* in the ordering. Once parameter estimates have been obtained, a WTP measure can be derived for each attribute using the transformation $-\gamma_j / \gamma_p$, where γ_p is the estimated price coefficient, and γ_j is the coefficient for attribute *j* (Bateman *et al.*, 2002, p. 283).

4. Household Survey and Sample Characteristics

4.1 Study region and sampling framework

We conducted an interview-based household survey in 2006 in Pernambuco State in NE Brazil. The NE is the poorest region of Brazil, with an average per capita income less than half of the country's overall average. Also in terms of other development indicators, the NE performs significantly worse than the rest of the country: while in 2005 Brazil had a human development index (HDI) of 0.79, the NE had an HDI of 0.72 (UNDP, 2007). With an average per capita consumption of 46 kg per year, cassava also plays a somewhat more important role in the NE than in the rest of the country, where consumption levels are around 40 kg per year (World Bank, 1997). On average, root and tuber crops, of which cassava is the most important in Brazil, account for about 10% of calorie intakes in the NE. Fresh cassava is eaten during six months of the year. Normally the root is boiled, sometimes it is fried or grilled. Cassava flour is used all the year around (González *et al.*, 2005).

Pernambuco is one of 9 states in NE Brazil; it is typical for the region in terms of household incomes, other development indicators, and also cassava consumption (World Bank, 1997). Fifty-three percent of the population in Pernambuco live below the $2 a day (purchasing power parity) poverty line, as compared to 54% for the NE as a whole (IBGE, 2003).[6] Pernambuco state was chosen on purpose, in order to keep the data collection manageable. Within the state, we concentrated on medium-sized municipalities. We did not include larger cities, because consumers there rarely consume fresh cassava and are not the primary target group of cassava biofortification. On the other hand, we also decided not to focus on purely rural areas, where most of the households are involved in farming. While farm households belong to the biofortification target group, many of them produce cassava themselves, so that it would have been difficult to separate consumer attitudes from issues of crop variety adoption. Of course, farmer adoption of biofortified varieties is also a very important component, which we do not address here. Interestingly, however, Heyd (2007) showed, for biofortified sweet potatoes in Uganda, that farmer adoption is largely driven by consumer acceptance, as this is the precondition for being able to market surplus production.

The four medium-sized municipalities Araripina, Lagoa Grande, Correntes, and Itambe were purposely selected, as they represent the socioeconomic, ethnic, and dietary spectrum of Pernambuco state well. We used living standard measurement survey data (World Bank, 1997) to select these municipalities. In the sampling framework, each of the four municipalities was stratified into zones, before households within the zones were selected randomly. The overall sample comprises 414 households. Due to the specific focus, the sample is not representative of the entire population in NE Brazil, but it is representative of households in medium-sized municipalities of NE Brazil, and thus of fresh cassava market consumers in the region.

[6] The poverty rate for Brazil as a whole is 36%.

4.2 Sample characteristics

The 414 households in the four municipalities were interviewed face to face, based on a structured questionnaire that was carefully designed and pre-tested. The interviews were carried out in Portuguese by a team of four female enumerators that we had hired locally. The enumerators were familiar with health issues in general and VAD in particular, as they had previously carried out surveys for the government's health service. They were trained for the purpose of this study and during the survey were always together with the principal researcher, so that ambiguities could be clarified on the spot. Interviews were conducted with the person responsible for food purchases. Apart from the CV and CM questions, the structured questionnaire covered general household characteristics and different consumer perceptions. While in general, people were very willing to answer the questions, 7% of the selected households refused to participate; they were replaced by other households on a random basis.

Some descriptive statistics are shown in Table 1. Most of the interviewees were female (93%); around 50% were housewives; less than 10% had formal employment, most of them with government organizations. The mean level of education is 4.8 years of schooling, and the average per capita income is 166 reais per month (US $78). Yet there are notable differences between the four municipalities: Araripina and Correntes have the lowest income levels, whereas Lagoa Grande has the highest.

4.3 Prior knowledge about vitamin A

As mentioned above, the government of Brazil has an ongoing vitamin A supplementation program. There are also similar programs for other micronutrients like iron and iodine, which are complemented by school feeding and nutrition education campaigns (Health Ministry of Brazil,

2007). In our survey, 85% of the respondents knew about these types of nutrition programs, but only 55% participated (Table 1). Regarding the vitamin A supplementation program in particular, 57% did not know that it exists for pregnant and lactating women, while 30% did not know that it exists for children. Also more generally, awareness of vitamin A is relatively low among the households sampled: only 47% knew something about this micronutrient. As consumer knowledge about the role of vitamin A in the diet is expected to be a crucial determinant of attitudes towards biofortified cassava, some simple background information was provided during the survey. To minimize a possible interviewer bias, a script was developed and translated into Portuguese. The script was discussed with local health workers and tested in a pilot study. During the survey, it was read to respondents before eliciting the stated preference data (see the Appendix for the English version of the script). To avoid confusion, during the survey we did not differentiate between provitamin A, which is contained in plant products, and vitamin A, which is contained in animal products.

4.4 Prior knowledge and perceptions about GM crops

Prior knowledge levels about GM crops were also very low among survey respondents. This has also been observed in other developing countries (e.g., Krishna and Qaim, 2008). Table 2 shows that only 25% had ever heard about GM crops before. Among these, 89% stated that they had only minor knowledge; no one claimed to have comprehensive information. We also asked this sub-sample about the main sources of information; 94% said that they had heard about GM crops on television; 13% had received information about GM crops from educational institutions, and 12% through the radio and print media.

Given the low knowledge levels about GM crops, we were again using a script to give respondents more background information (see Appendix). In this script, we also explained the

idea of cassava biofortification – either through conventional or GM breeding techniques. The exact wording of the script was discussed with a wide variety of experts, including biotechnologists, agronomists, nutritionists, social scientists, and selected local stakeholders, to reduce a potential bias. During the survey the explanations in the script were supported through pictures of existing white and yellow cassava varieties.

Afterwards, we asked respondents to clarify their preferred method of increasing vitamin A levels in cassava. Around 54% stated that they would prefer conventional breeding techniques, while 40% chose the GM option. The latter is somewhat surprising, because at this stage we had not indicated that GM techniques might lead to higher levels of vitamin A than conventional breeding. However, many respondents said that they would prefer GM because they feel that modern laboratory techniques might result in a safer product. Some also explained that they trust that researchers would know what they do and would not develop products that threaten human health. These responses underline that the public perception about modern science is generally quite favourable in the study region. We also asked more specifically whether respondents would fear health risks associated with GM crops. Although nobody believed that GM crops are absolutely safe, only a relatively small share (22%) said that they would be concerned about health risks (Table 2).

The interviewees were then informed about the difficulty of increasing vitamin A content in cassava significantly through conventional breeding, before they were asked whether or not they would support the introduction of GM biofortified cassava. A four-point scale ranging from 1 “strongly opposing” to 4 “strongly supporting” was used. A fifth option “can’t tell” was allowed. Almost 75% responded that they would strongly or moderately support the technology, while 20% were strongly or moderately opposing its introduction; 5% could not decide on a clear position. The main reasons for supporting GM biofortified cassava were expected nutritional

benefits (68%) and possible advantages for farmers (6%). On the other hand, potential risks (80%), a general unwillingness to eat new products (12%), and ethical concerns (12%) were reasons cited among opponents.

5. Estimation Results

Using the four-point scale data about consumer support of GM biofortified cassava, we estimated an ordered logit model to explore the factors underlying consumer perceptions. As explanatory variables, we included socioeconomic factors similar to those used in previous studies (e.g., Krishna and Qaim, 2008; Han and Harrison, 2006). Table 3 shows the estimation results. Age and the dummies reflecting: trust in regulatory authorities; perceived GM health risks; and access to mass media are all statistically significant. Consumers who trust the regulatory authorities are more supportive of the GM technology, while people who are concerned about GM health risks tend to oppose its introduction. This is not surprising. Access to mass media increases the probability of GM support in NE Brazil, suggesting that media reports about GM crops are rather positive. In other countries it has also been shown that mass media has a significant influence on consumer perceptions towards GM crops, although the effects can be different. In China, for instance, government controls the media, and official government positions on biotechnology are positive, so that consumers who use the media frequently tend to have a positive attitude (Xi and Harris, 2006). In India, by contrast, media reports about GM crops are rather negative, so that frequent media use leads to lower consumer acceptance (Krishna and Qaim, 2008). Likewise, age has been shown to have positive effects in some cases, but negative ones in others. In our case, older respondents have a more positive attitude towards GM biofortified cassava, which is consistent with findings by Kim and Boyd (2004) and Han and Harrison (2006).

5.1 Willingness to pay

As explained above, we use a double-bounded dichotomous choice CV approach to estimate consumers' WTP for GM biofortified cassava. In the survey, we randomly assigned price bids in the range between 1% and 80% above current cassava market prices to the questionnaires.[7] This range was determined based on a pilot study, where we found that the great majority of consumers stated a positive WTP for biofortified cassava, in spite of the GM status and yellow colour. It should be noted, though, that positive price bids do not rule out the possibility of negative WTP results in the estimation procedure or vice versa (Krishna and Qaim, 2008).

While pre-testing the questionnaire we realized that many people were not very familiar with percentage figures, so we converted the percentage bids into monetary prices, using the current price paid for traditional cassava as the reference. That is, the dependent variable is a price mark-up over current market prices paid, measured in reais per kg. To control for differences in price levels, we included individually paid market prices as an independent variable in the WTP model (equation 3). Since this might be correlated with the error term, we used an instrumental variable approach to avoid an endogeneity bias.[8] Different socioeconomic and perception variables were included as covariates. The estimation results are shown in Table 4.

Predicted current price levels are associated with a relatively large positive and significant coefficient. For each additional real per kg that consumers currently pay for cassava, they are willing to pay additional 0.56 reais for GM biofortified cassava. Likewise, female respondents

[7] For the first bid, one of the following options was chosen: 1%, 2%, 5%, 10%, 15%, 20%, 30%, 40%, 50%, 60%, 70%, and 80%. The second bid was adjusted depending on the first response. When the responses to both bids were negative, we asked for reasons, in order to find out whether the particular bids were just too high or whether the respondents refused to consume GM foods altogether. The latter was observed in a small number of cases. In the estimation procedure, these were treated as normal "no-no" responses (response group 1 in equation 1 above), as WTP in such situations is definitely smaller than the lower price bid.

[8] To predict price levels, municipality and place of purchase dummies were used as instruments.

are willing to pay significantly more for GM biofortified cassava than males. This is in contrast to previous studies that had shown for different countries that women are less open to GM foods than men (e.g., Krishna and Qaim, 2008; Curtis *et al.,* 2004). However, these previous studies referred to first generation GM crops without direct advantages for consumers. Biofortified cassava is different, as it could reduce VAD and thus bring about important nutrition and health benefits. Since women are often more concerned about the nutritional status of family members, especially children, the positive coefficient is to be expected. Similarly, the positive effect for households with small children is expected for this particular technology. Education and participation in nutrition programs can be considered as proxies for nutritional awareness among respondents. They are not significant, which might be due to the fact that we gave all respondents some background information about the role of vitamin A, so that prior differences in knowledge and awareness were reduced. Neither did we find a significant effect for household income, which might partly be due to correlation with other explanatory variables in the model. We also tried income group dummies instead of a continuous variable, which did not change the results. We therefore conclude that income has no important influence on WTP when other household characteristics are controlled for.

The number of times that a household consumes cassava per week has a negative impact on WTP. This is somewhat surprising, because more frequent consumption also implies higher nutritional benefits. Yet it is possible that people who consume cassava regularly as their primary staple food are more sceptical of potential risks that might increase with the dose consumed.[9] Indeed, risk concerns have a negative influence on WTP. Consumers who feel that GM food is associated with health risks are willing to pay 0.29 reais less than their counterparts who believe

[9] One might also suspect that the frequency of cassava consumption is to some extent picking up an income effect. Yet, in our sample the two variables income and frequency of consumption are not correlated very closely.

that GM products are relatively safe. Also, respondents who would prefer vitamin A increases through conventional breeding approaches have a lower WTP for GM varieties. As risk and consumer openness towards new food products are partly controlled for in the model, this latter effect might be due to ethical concerns.

We also tested whether respondents who knew about GM crops before have a different WTP than those for whom the information provided during the survey was the first and only impression. The respective prior knowledge dummy has a positive coefficient, which is significant at the 10% level. This suggests that existing information sources in NE Brazil report about GM crops in a more positive way than we did in the survey. However, the marginal effect of prior knowledge on WTP is small (0.09), suggesting that the information we provided did not lead to any sizeable bias.

On average, consumers are willing to pay 0.49 reais more (a 64% price premium) for GM biofortified cassava than for traditional cassava without vitamin A. Differences across the four municipalities are relatively small.[10] The estimated premium appears quite high on first sight, and in comparison with previous results from other countries. In a meta-analysis of 25 valuation studies from different regions, Lusk *et al.* (2005) reported that, on average, consumers require a 20-30% price discount for GM foods; though most of the underlying studies refer to first generation GM crops. In developing countries, required discounts are generally lower, and in some cases consumers are even willing to pay a premium for first generation GM crops (e.g., Curtis *et al.,* 2004). For second-generation GM crops, almost all available studies refer to consumers in the US. Onyango and Nayga (2004), who analyzed GM breakfast cereals with higher nutrient contents, found relatively positive consumer attitudes, but they did not report a

[10] We also tried to include dummies for the municipalities into the WTP model, but the coefficients were individually and jointly insignificant.

mean WTP. Loureiro and Bugbee (2005) found that consumers are willing to pay price premiums of 3-4% for tomatoes with better nutritive or enhanced flavour characteristics, while Han and Harrison (2006) reported a mean premium of 16% for GM beef with less fat and lower cholesterol. Lusk (2003) analyzed the WTP of US consumers for GM golden rice with provitamin A, and estimated a premium of 25-44%, depending on the particular model used. Against this background, the 64% premium found here for NE Brazil is consistent with the fact that problems of VAD are more widespread and severe than in the US, and thus potential benefits of vitamin A biofortification are bigger.

However, poor consumers in developing countries face substantial income constraints. What does the estimated premium mean in terms of household budget share? Based on our sample data, mean monthly per capita expenditure for cassava is around 3 reais ($1.42), accounting for 1.8% of average household income. A 64% price premium for biofortified cassava at constant consumption levels would increase monthly expenditure to 4.9 reais, or 3% of household income, indicating the strength of preference/acceptance for more nutritious cassava. It should also be noted that cassava is characterized by high seasonal price variation anyway, with typical price ranges between 0.4 and 1.2 reais per kg. Nonetheless, as pointed out above, the idea is not to really sell biofortified cassava at a premium, because this could lead to access problems among the poor. The large WTP is simply a clear indication of positive acceptance levels and an expected increase in consumer utility through cassava biofortification.

5.2 Contingent ranking

As explained above, we used a CM approach to better understand the trade-offs between different cassava attributes. During the survey, we carried out a contingent ranking experiment, in which respondents were asked to rank between a set of alternatives, each describing a cassava type with

different characteristics. We identified four attributes of interest, namely GM status, vitamin A content, colour, and price. The first three attributes have two levels of valuation each, whereas for price we included three different levels (see Table 5). This implies a total of 24 (2^3 x 3) theoretically possible alternatives. However, many of these alternatives were not realistic and would have confused the respondents, especially also against the background of the information script used, since this had stated that vitamin A is always associated with yellow colour. Therefore, while we allowed yellow colour without vitamin A, we excluded all white colour/vitamin A combinations. Other potentially confusing alternatives were also excluded. For instance, since the status quo (conventional, white cassava without vitamin A at current market price) was always part of the choice set, we refrained from including the same type with price variations.

Thus, the number of alternatives was reduced to 10 realistic cases,[11] which, however were still too many to rank consistently, as the cognitive burden for respondents increases with the number of alternatives presented (e.g., Foster and Mourato, 2002). Based on a pilot study, we decided to present four of the 10 alternatives to each respondent – namely the status quo plus three other randomly selected ones, which were varied between respondents. Confronting respondents only with a relatively small set of alternatives clearly increases the probability of consistent answers (Bateman *et al.*, 2002, p. 265). During the CM experiment, cards with pictures of white and dark yellow (almost orange) cassava and GM food labels were used as visual aids.

The coefficients associated with each attribute were estimated using the rank-ordered logit model (equation 6). We only estimate main effects, assuming that the preferences level of each attribute is independent of the level of other attributes. For choice models, main effects typically

[11] We acknowledge that not considering all combinations might reduce statistical efficiency, but decided that this drawback is outweighed by the greater reliability of the ranking through higher market realism and lower cognitive complexity.

account for 70-90% of explained variance (Louviere *et al.*, 2000, p. 94). Here, tests with different specifications confirmed that ignoring interaction terms does not lead to a systematic bias in our model. The estimation results are shown in Table 6. All estimated coefficients are statistically significant. Since the most preferred alternative was ranked with number 1, and the least preferred with 4, positive coefficients indicate a negative preference for the respective product characteristic, while negative signs imply a positive preference. Price, GM status, and yellow colour have positive signs. This means that consumers prefer a cheap, GM-free, and white cassava, which is plausible. Conversely, the negative coefficient for vitamin A content implies a positive preference for vitamin A biofortification, and the coefficient is quite large in absolute terms.

We also calculated the partial WTP for each attribute (Table 6). Vitamin A content has the biggest utility effect: consumers are willing to pay 1.23 reais per kg more for cassava that contains provitamin A. Since 53% of the respondents did not know anything about vitamin A prior to the survey, this result is obviously driven by the nutrition and health information provided by us. Therefore, one should not conclude that introducing vitamin A biofortified cassava would, *per se*, lead to increased demand and prices. Nevertheless, the result shows that nutritional enhancement of food crops has the potential to increase consumer utility when accompanied by an objective educational campaign. Yellow colour, which is connected to provitamin A, reduces the WTP by 0.22 reais on average, whereas GM status reduces the WTP by 0.47 reais. These are important findings for biofortification research programs.

The CM approach used here assumes that the value of the whole good is equal to the sum of the parts. We can hence calculate the mean WTP for a GM biofortified cassava as 1.23 reais minus 0.47 reais (for GM status) minus 0.22 reais (for yellow colour) to result in a value of 0.54 reais. This is a 70% premium over the current average market price. The CV approach above

generates a mean WTP of 64% over current market prices, which is slightly lower, but still in the same order of magnitude. Hence, both the CV and CM approaches generate consistent results, suggesting that the results are not greatly influenced by the study design and methodology. Nevertheless, both approaches depend on stated preference data, which might be hypothetically biased, so that it would be a mistake to place particular confidence in the exact numbers.

6. Conclusion

We have examined consumer attitudes towards GM cassava with high provitamin A content in NE Brazil. This is among the first research studies to analyze the acceptance of second generation GM crops in a developing country. Given that different crop technologies with enhanced nutritive characteristics, targeted at developing countries, are currently in the pipeline, more knowledge about related consumer preferences is definitely needed.

Our findings suggest that attitudes towards GM biofortified cassava are strongly positive among consumers. Three-quarters of all respondents in our survey said they would support the introduction of this new technology. Using contingent valuation techniques, we estimated that consumers are willing to pay an average price premium of 64% for GM biofortified cassava. This is high but not unrealistic, given that vitamin A deficiency and related health problems are widespread in NE Brazil. Female respondents and households with small children have a higher WTP; these are also the main target groups of provitamin A biofortification. On the other hand, those who have ethical concerns, or are particularly worried about health risks of GM crops, have a lower WTP, but the proportion of people in our survey with strong objections is very small. Household income levels do not appear to have a significant effect separate from other socio-economic characteristics. These results bode well for the introduction of GM biofortified cassava in Brazil. They are also consistent with earlier findings from developed countries, notably the

US, showing that second generation GM crops with direct consumer benefits are valued more positively than first generation technologies.

We also estimated the WTP using a contingent ranking choice experiment. Overall, we obtained very similar results as with the contingent valuation methodology. Yet we were also interested in understanding the trade-offs between different cassava characteristics and therefore estimated a partial WTP for each relevant attribute. For the vitamin A attribute alone, the average consumer is willing to pay a large premium of 160%. However, a discount is required for the cassava colour change from white to yellow (-29%), and an additional discount results from the fact that the cassava is genetically modified (-61%). This is an important finding for biofortification programs, having to make a decision between conventional and GM breeding techniques. Sometimes, conventional breeding is not an option, because there are crop species that do not contain certain micronutrients. When there is a choice, however, the conventional approach seems to be preferred by consumers. This holds true at least in the present situation, where the public GM crop debate is dominated by perceived technology risks and concerns. A GM approach can also be associated with significantly higher regulatory costs. These are not arguments against GM techniques *per se*, especially not when these can result in more effective micronutrient increases, as is true for provitamin A cassava. But the trade-offs need to be considered, and decisions be made case by case.

It should be stressed that our analysis builds on stated preference data, which are often associated with a certain hypothetical bias. Moreover, results of such analyses always crucially depend on the amount and quality of information that respondents have. We found that the level of awareness of both vitamin A deficiency problems and GM crops is generally low among consumers in NE Brazil, so that we had provided background information during the survey. While this approach offers an initial familiarization, it does not allow survey respondents to

digest and reflect. Although we have tried to reduce any potential bias as much as possible, these aspects should be kept in mind when interpreting the results.

In any case, provitamin A cassava, like most other biofortified crops targeted at the poor, are developed by public sector organizations that have no intention to sell products at a price premium. Therefore, the WTP analysis should not be misinterpreted as a strategy to determine feasible price mark-ups, but rather as a tool to better understand consumer preferences. Our general finding is that NE Brazilian consumers would accept GM cassava with increased levels of provitamin A and would appreciate the associated nutritional benefits. Furthermore, using the WTP approach, we are able to quantify this willingness to accept such a product, and find it to be strong, notwithstanding its coincident detrimental characteristics (colour and GM).

But clearly, consumer awareness and information play an important role. The details provided during the survey on vitamin A and health problems associated with deficiencies probably contributed to the positive attitudes towards biofortification. Without appropriate awareness creation, acceptance problems might potentially occur, especially when fears about GM crop risks are fuelled by anti-biotechnology pressure groups. Therefore, promoting the flow of objective information should be an integral part of efforts to develop and disseminate second generation GM crops in developing countries.

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Table 1

Descriptive statistics

Variables	Araripina	Lagoa Grande	Correntes	Itambe	Total
Female respondent, dummy (%)	91.61	88.16	96.05	96.26	93.00
Age of respondent (years)	39.85	44.29	39.26	39.55	40.48
	(14.01)	(13.98)	(13.63)	(13.70)	(13.94)
Households with children < 5, dummy (%)	71.61	56.58	72.37	65.42	67.39
Education of respondent (years)	4.54	5.22	5.39	4.57	4.83
	(3.92)	(4.46)	(4.45)	(3.91)	(4.12)
Per capita monthly household income (reais)	156.10	199.31	154.25	165.37	166.09
	(98.91)	(139.61)	(133.04)	(103.22)	(115.77)
Occupation of respondent, dummies (%)					
Formal employee	9.68	14.47	9.21	4.67	9.18
Trader	8.39	6.58	1.32	8.41	6.76
Farmer	9.03	9.21	18.42	0.00	8.45
Informal employee	13.55	6.58	15.79	5.61	10.63
Not working	1.94	2.63	3.95	4.67	3.14
Housewife	44.52	44.74	42.11	64.49	49.28
Pensioner	12.90	15.79	9.21	12.15	12.56
Cassava price paid (reais/kg)	0.88	0.97	0.64	0.56	0.77
	(0.31)	(0.21)	(0.16)	(0.18)	(0.29)
Cassava consumption (times per week)	3.07	2.85	2.85	2.48	2.84
	(1.39)	(1.27)	(1.62)	(1.05)	(1.35)
Participation in nutrition programs, dummy (%)	54.19	57.89	57.89	53.27	55.31
Trust in regulatory authorities, dummy (%)	50.97	23.68	34.21	55.14	43.96
Access to mass media, dummy (%)	79.35	77.63	81.58	84.11	80.68
Willingness to eat new products, dummies (%)					
High willingness	7.10	7.89	7.89	11.21	8.45
Average willingness	52.26	63.16	67.11	60.75	59.18
Low willingness	24.52	14.47	11.84	9.35	16.43
Avoid	16.13	14.47	13.16	18.69	15.94

Notes:

US $1 = 2.12 reais according to the official exchange rate in late 2006.

For continuous variables, mean values are shown with standard deviations in parentheses.

Table 2

GM knowledge and perceptions

Variables	Araripina	Lagoa Grande	Correntes	Itambe	Total
Prior knowledge about GM crops, dummy (%)	27.24	25.00	23.68	22.43	25.12
Knowledge level about GM crops (%) [a]					
Comprehensive knowledge	0	0	0	0	0
Some knowledge	9.30	15.79	0	16.67	10.58
Minor knowledge (only heard)	90.70	84.21	100	83.33	89.42
Perceived GM health risks, dummy (%)	18.60	26.32	27.28	20.83	22.12

[a] Knowledge levels refer to respondents' own assessments. Only respondents who had heard about GM crops before were asked about their knowledge levels.

Table 3

Ordered logit model for explaining consumer support of GM biofortified cassava

Variables	Coefficient	Std. error
Female respondent	-0.45	0.44
Age	0.02*	0.01
Children <5	0.14	0.25
Education	0.03	0.03
Per capita monthly household income	0.00	0.00
Trust in regulatory authorities	0.55**	0.22
Perceived GM health risks	-3.05***	0.46
Access to mass media	0.48*	0.29
Intercept	1.96***	0.72
Log likelihood	-357.78	
Chi-squared	54.68***	

Notes:

The dependent variable is ranked between 1 and 4, where 1 means "strong opposition" and 4 means "strong support".

The number of observations is n=388; 26 "can't tell" responses were excluded.

*, **, *** statistically significant at the 10%, 5%, and 1% level, respectively.

Table 4

WTP model for GM biofortified cassava

Variables		Coefficient	Std. error
Cassava price paid, predicted (reais/kg)		0.56***	0.11
Female respondent		0.14**	0.07
Age		0.00	0.00
Children <5		0.07*	0.04
Education		0.01	0.01
Participation in nutrition programs		0.01	0.04
Per capita monthly household income		0.00	0.00
Cassava consumption (times per week)		-0.03***	0.01
Perceived GM health risks		-0.29***	0.08
Trust in regulatory authorities		-0.02	0.04
Access to mass media		0.04	0.05
Willingness to eat new products	a. Average willingness	-0.08	0.07
(*reference is high willingness*)	b. Low willingness	-0.07	0.08
	c. Avoid	-0.01	0.08
Preferred way to increase vitamin A	a. Through conventional	-0.27***	0.04
(*reference is through GM*)	b. Indifferent	-0.25***	0.08
Prior knowledge about GM crops		0.09*	0.05
Intercept		0.06	0.16
Log likelihood		-442.90	
Chi-squared		104.07***	

Notes:

The number of observations is n=414.

*, **, *** statistically significant at the 10%, 5%, and 1% level, respectively.

Table 5

Cassava attributes and levels of valuation in contingent ranking experiment

Attribute	Levels
GM status	GM cassava Conventionally bred cassava
Vitamin A content	Contains vitamin A Does not contain vitamin A
Colour	Yellow White
Price [a]	+10% relative to current market price Current market price -10% relative to current market price

[a] The percentage price differences were converted into monetary figures during the survey.

Table 6

Rank-ordered logit model for GM biofortified cassava

Variables	Coefficient	Std. error	WTP
Price	1.93***	0.70	
GM status	0.91***	0.09	-0.47
Vitamin A content	-2.36***	0.15	1.23
Colour (yellow)	0.42***	0.09	-0.22
Log likelihood	-1105.95		
Chi-squared	419.53***		

Notes:

The number of observations is n=1656.

*, **, *** statistically significant at the 10%, 5%, and 1% level, respectively.

Appendix

Information script on vitamin A

Vitamin A is an essential nutrient for the human body. It plays an important role in body functions such as vision, immune defence, maintenance of body linings, and cell development and reproduction. Many food crops contain vitamin A, including those that have a deep yellow or orange colour such as carrots, mango, and papaya; green vegetables such as broccoli and spinach; and animal products such as milk, eggs, and meats, including liver. However, many people do not eat sufficient amounts of these products, either because they are not available, their price is too high, or they simply do not belong to traditional, local dietary habits. Therefore, in poor countries and regions vitamin A deficiency is widespread, leading to serious nutrition and health problems. Due to their high vitamin A requirements, children and pregnant and lactating women are particularly affected. Vitamin A deficiency increases the prevalence and severity of infectious diseases, such as measles. It is also associated with higher child mortality and problems of eyesight; in extreme forms, vitamin A deficiency can even cause permanent blindness.

Information script on GM crops and biofortified cassava

A genetically modified (GM) crop – or transgenic, as they are also called – is a crop into which a gene from another organism has been inserted in the laboratory, in order to generate a new trait in the plant, which in many cases could not be achieved with conventional breeding methods. New traits of GM crops can include higher yield levels, better resistance to pests, but also higher amounts of vitamins and other nutrients for

human consumption. GM crops are being grown in the USA and Canada, but also in Argentina, Brazil, and several countries in Asia. Nevertheless, there is a controversial public debate about their usefulness and safety. Proponents of GM crops point to potential economic and nutrition benefits, but there are also sceptics, who are concerned about possible risks, including many consumers in Europe. Various non-governmental organizations are voicing against the introduction of GM crops, due to possible long-term adverse impacts on human health and the environment. Such negative effects, however, have not occurred so far, although GM crops have already been used for several years and been tested extensively.

Researchers are currently developing a new type of cassava with higher levels of vitamin A to reduce nutrition and health problems of vitamin A deficiency. Traditional cassava as such is not an important source of vitamin A. One approach is to use conventional breeding techniques to increase vitamin A levels. Another approach is to use GM techniques, where genes from other organisms are inserted into cassava in the laboratory. In any case, the new cassava type, which is called biofortified cassava, will contain more vitamin A, but will have the same taste, texture, and cooking properties as the traditional cassava that you are consuming now. Only its colour will change from white to dark yellow, caused by the higher vitamin A content.