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PUBLIC ATTITUDES TOWARDS GENETICALLY MODIFIED PROVITAMIN A CASSAVA IN BRAZIL

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TABLE OF CONTENTS

Chapter number	Chapter title	Page number
I.	Introduction	1
II.	'**Consumer Preferences for Table Cassava Characteristics in Pernambuco, Brazil'** Carolina Gonzalez and Nancy Johnson Accepted for publication by *Brazilian Review of Economics and Agribusiness*	21
III.	**'Consumer Acceptance of Second Generation GM Foods: The Case of Biofortified Cassava in the Northeast of Brazil'** Carolina Gonzalez, Nancy Johnson and Matin Qaim Published as Gonzalez *et al*. (2009) in the *Journal of Agricultural Economics*	38
IV.	'**Stakeholder Positions Toward GM Food: The Case of Vitamin A Biofortified Cassava in Brazil'** Carolina Gonzalez, James Garcia and Nancy Johnson Published as Gonzalez *et al*. (2009) in *AgBioForum*	70
V.	Conclusions	97
VI.	Annex	V
	Summary	XXVI
	Zusammenfassung	XXIX

CHAPTER I

INTRODUCTION

Genetically modified organisms (GMOs) or living modified organisms (LMOs) in terms of the Cartagena Protocol on Biosafety (CPB) are defined as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (CPB, article 3). This type of technology has been received by the general public with a high level of controversy. Promoters of GMOs highlight their benefits, such as opportunities for farmers to reduce their production costs and therefore increase their profits. GMOs could also provide other potential benefits, such as improving environmental quality, enhancing food quality, and mitigating world food shortages. Despite these potential benefits, many view biotechnology as a risky process, underlining the potential unknown effects of modifying genes and nutritional contents of food. In addition, concerns about environmental quality and moral issues are other factors that influence public attitudes (Han and Harrison, 2006).

Researchers began to develop varieties of genetically modified (GM) crops in the 1980s. These plants are the so-called 'first generation' of GMOs in agriculture—that is, crops that involve modified traits to provide direct benefits to farmers by lowering production costs or enhancing crop productivity (e.g., tolerance to herbicides, insect resistance). Most of the available socioeconomic studies, either related to impacts or public attitudes, refer to these first-generation GM technologies. There is a growing body of literature about their benefits and risks, both in developed and developing countries (e.g., Hareau *et al.*, 2004; Qaim and Zilberman, 2003; Qaim and Janvry, 2003; Pachico and Wolf, 2002).

So-called 'second-generation' GM crops are different, as they involve more direct consumer benefits through enhanced quality attributes or nutritional characteristics (Jefferson-Moore and Traxler, 2005). So far, there are relatively few socioeconomic studies available related to these second-generation GM crops, mainly because they are not yet on the market. It might generally be expected that consumer attitudes towards such crops would be more positive because of the direct consumer benefits (Onyango and Nayga, 2004). Indeed, results from a few studies that were carried out in developed countries about consumer attitudes toward GM foods suggest

that attitudes can change: opposition against first-generation GM crops may be reduced when direct consumer benefits are involved (Loureiro and Bugbee, 2005; Burton and Pearse, 2002).

Large segments of the populations in developing countries suffer from micronutrient malnutrition, especially children and pregnant and lactating women. This type of malnutrition is a result of insufficient intake of vitamins and minerals (iron, iodine, zinc, etc.) required by the human body. Vitamin A deficiency (VAD) is a health problem in many developing countries (WHO, 2008). VAD increases the prevalence and severity of infectious diseases (morbidity and mortality), and may cause severe eye problems, including permanent blindness. For any country's economy, VAD implies high costs for the health system and for the economy as a whole (Stein *et al.*, 2005). Some approaches are being used to combat micronutrient deficiencies, such as food supplementation programs, public health actions, nutritional education, and industrial fortification. Biofortification is a newly developed strategy to increase the micronutrient contents of staple food crops through breeding, with the objective of providing people with specific micronutrients. Most staple crops are being biofortified by conventional plant breeding. Yet there are also species in which certain micronutrients are absent or present in very small amounts, so the use of biotechnology holds great promise. One such case is cassava (*Manihot esculenta* Crantz), which contains provitamin A (carotenoids) but only at relatively low levels. Genetic modification could potentially boost the crop's provitamin A content, thus reducing more effectively the problems of vitamin A deficiency in cassava-eating populations. GM cassava might, however, face acceptance issues because of consumer concerns about health and environmental risks or potential ethical objections.

The present study examines consumer attitudes towards GM cassava with increased levels of provitamin A in Northeast (NE) Brazil. This implies that consumers can weigh the benefits and costs of different aspects of a product, including the GM status, so that they can decide whether or not the product satisfies their needs. In addition, the position of stakeholders regarding the introduction of second-generation GM foods was analyzed. Experiences worldwide show that the position of stakeholders can importantly influence the efficiency of GM regulatory approaches and the success of new technology releases.

This dissertation is a compilation of three articles related to different aspects of the research project. The introduction aims to provide background information that is not presented in the articles themselves or is not presented in detail and has been organized into seven sections as follows: section 1.1, the global status of second-generation GM crops; section 1.2, levels of vitamin A deficiency in NE Brazil; section 1.3, the local relevance of cassava; section 1.4, an overview of GM crops in Brazil; section 1.5, additional details of research objectives and concrete study questions; section 1.6, primary data collection procedures for empirical analyses; and section 1.7, dissertation structure.

1.1 Second-Generation GM Crops

The introduction of second-generation GM crops generates optimism in the biotechnology industry. Studies have shown that these value-added crops can potentially provide the boost desired by the agricultural biotechnology sector and enhance the economic wellbeing of both consumers and producers (Giannakas and Yiannaka, 2008). Until early 2003, FlavrSavr Tomato was the only altered second-generation product available in the United States (Rousu *et al.*, 2005). Over the last decade, the industrial and public sectors have made significant investments in the development of second-generation GM crops. The growing list of such crops includes Golden Rice to prevent vitamin A deficiencies; rice fortified with iron, calcium, and zinc; canola and soybean with enhanced vitamin E; potato with an altered starch structure; various oilseed crops rich in polyunsaturated fatty acids; oilseeds with omega-3 fatty acids; and broccoli with antioxidants and anti-carcinogens (Huot, 2002).

Despite potentially higher consumer benefits and acceptance levels, second-generation GM crops generate certain concerns. In particular, they have been criticized by different non-governmental organizations (NGOs). Points of critique, in addition to those that also apply to first-generation GM crops, have to do with the (a) the false health claims that are made, (b) the belief that nutritional benefits could be achieved more sustainably through dietary diversification, and (c) the concern that poor consumers in developing countries may not be able to access such foods because of steep price markups. On the other hand, promoters of GM crops highlight their benefits, such as a better conservation of food products, improved nutrition and health status among consumers, and better taste (Le Marre *et al.*, 2007).

The literature addressing the potential benefits of second-generation GM crops and the attitudes of consumers towards these crops is still relatively scarce. The few available studies have shown that acceptance levels could increase significantly over those of first-generation GM crops (Anand, Mittelhammer and McCluskey, 2007; O'Connor *et al.*, 2006). In China, for instance, consumers are willing to pay a 38% premium for Golden Rice (Li *et al.*, 2002). Pachico and Wolf (2002) found that the willingness of Colombian consumers to purchase GM crops increases when quality-enhancing traits are involved. Lusk and Rozan (2005) concluded that the way to increase the acceptance of biotechnology food is by developing products with clear benefits for consumers. This does not necessarily reduce the overall perceived risk for consuming GM crops in Japan and European countries, but it could change the risk-benefit ratio at a global level.

GM crops have the potential to address several causes of hunger in developing countries by increasing food availability and improving nutritional content (Capell *et al.*, 2007; Costa-Font, Gil and Traill, 2008). The future of GM crops in general and that of second-generation crops in particular will primarily depend on consumer attitudes, which are significantly influenced by the information given in the media (Anand *et al.*, 2007) and other variables, such as the level of consumer aversion to genetic modification or the market share of the first-generation GM products (Giannakas and Yiannaka, 2008). It is therefore important to take those variables into account when conducting consumer surveys on quality-enhanced GM crops.

1.2 Vitamin A Deficiency (VAD) in the Northeast of Brazil

Vitamin A is provided through retinol (preformed vitamin A) in animal products or through carotenoids (provitamin A) available in fruits and vegetables. Beta-carotene is the most important carotenoid in plants, which is transformed into vitamin A by an enzymatic action in the digestive system (IOM, 2004). Insufficient intake of provitamin A causes a deficiency of this micronutrient. Because VAD is a major health problem in developing countries, it is important to understand its causes so that governments and other institutions can apply the best strategies to combat this type of malnutrition. A number of studies on micronutrient malnutrition and its causes have been carried out in developing countries (Ramakrishnan *et al.*, 2004; Hinderaket *et al.*, 2002; Bouis and Novenario-Reese, 1997). Results show that this type of malnutrition is closely related to aspects such as food availability, variety of diet, and level of income (Abdulai and

Aubert, 2004). In addition, variables like nutritional awareness of mothers and access to health services are also important determinants of micronutrient status (Macdonald *et al.*, 2004).

NE Brazil is one of the country's poorest regions (UNDP, 2007), with high levels of poverty and malnutrition (WHO, 2008). Nutritional deficiencies are reported in both urban and rural populations at many sites (Santos, 2002; Mora, Gueri and Mora, 1998), being persistent in this part of the country (Martins *et al.*, 2007; Ashworth, Morris and Lira, 1997). According to the results of biochemical tests, more than half the children and a significant percentage of pregnant and lactating women suffer from VAD (Santos, 2002). To better understand the regional scenario, the vitamin A consumption levels of households were estimated from food expenditure data.

The most recent nationwide survey of Brazilian household living standards, "Pesquisa de Orcamentos Familiares" (POF), was conducted in 2002-2003 (IBGE, 2003a) and includes food expenditure data that is nationally representative. Food expenditure surveys have the advantage of providing food consumption data that can be used to estimate nutrient consumption in such a disaggregated form that micronutrient consumption can be calculated there from. The main disadvantage is, however, that respondents tend to have problems remembering what they purchased and, as a result, the amount of food purchased might be over- or underestimated. Nonetheless, the use of food expenditure data is still a common and acceptable approach for general food and nutrient consumption assessments (Smith, Alderman and Aduayom, 2006; Heyd, 2007).

The Brazilian Food Composition Table, known as TACO (http://www.unicamp.br/nepa/taco/contar/taco_versao2.pdf), was used to convert the amount of food consumed into nutrient values. The USDA food composition table was then used to complement the TACO for individual commodities (USDA, 1999). A limitation encountered during the study was the absence of national and international composition tables that accurately measured local diets in a given sub-region. Neither the USDA nor the TACO tables contain geographically specific food composition data (Calitri, 1999).

It was also necessary to determine the amount of carotenoids in the diet that is equivalent to a given amount of retinol (a form of vitamin A). Diverse unit equivalences have been used over the years. Nowadays, the biologic activity of vitamin A is expressed in Retinol Activity Equivalents (RAE), where one RAE is equal to one

microgram (µg) retinol (IOM, 2008). Because available data measure food consumption at the household level, it was necessary to calculate the per capita consumption of food. To determine intra-household distribution, the percentage of consumption was calculated for four target groups[1] by regressing the total amount of consumption to the per capita consumption and the number of individuals in each target group.

The Recommended Dietary Allowance (RDA) was used to determine the per capita dietary requirement of vitamin A for the human body to function properly in the case of each target group. The Food and Nutrition Board of the US National Academy of Science has established dietary reference intakes (DRIs) to serve as reference for nutrient needs. The RDA is one of four DRI indicators that aim to establish the minimum intake required to prevent deficiency diseases (IOM, 2008)[2]. Vitamin A consumption levels (µg/day) and levels of deficiency were calculated for several population groups, based on the aforementioned data and on other reference values.

Overall, data indicate that vitamin A deficiencies prevail throughout all NE Brazil (Table 1), with the states of Alagoas, Piaui, Paraiba and Pernambuco presenting the lowest percentage of households with adequate vitamin A consumption. Other studies conducted in Brazil revealed that, on average, there is sufficient availability of this micronutrient (1,909 µg/day) in both rural and urban areas (Morato, 2007); however, factors such as the unequal income distribution and a monotonous diet among the low-income population contribute to the high levels of VAD.

[1] Groups: children < 5 years; children between 6-14 years; women > 14 years; and men > 14 years.
[2] The other three types of DRI values are: Estimated Average Requirement (EAR), Adequate Intake (AI) and Tolerable Upper Intake Level (UL).

Table 1. Vitamin A consumption (µg/day) in NE Brazil by state and target groups

NE State	Vitamin A per capita consumption (µg/day)	Vitamin A consumption children < 5 years (µg/day)	Vitamin A consumption women (µg/day)
Maranhao	304.03	238.17	319.91
Piaui	283.37	241.94	307.68
Ceara	482.73	361.45	524.26
Rio Grande do Norte	381.89	462.07	387.67
Paraiba	282.47	287.78	264.77
Pernambuco	301.27	285.90	308.05
Alagoa	274.95	284.16	295.26
Sergipe	335.40	273.91	336.40
Bahia	361.04	287.90	343.77
Average	334.13	302.59	343.09
RDA	750	500	700

Source: Author's calculations based on household data from IBGE (2003a).

Relatively low levels of education and income characterize households in this part of NE Brazil. For a more disaggregated analysis, households were subdivided according to their level of income per household member: 64% ranked below half the minimum monthly wage (mmw),[3] while 8% had incomes more than four times the mmw. Previous studies indicated that vitamin A consumption is related to household income levels (Bouis and Novenario-Reese, 1997) and the results obtained herein confirm this general observation. The average consumption of vitamin A was found to be higher in high-income households than in low-income households, indicating that higher incomes will translate into a significantly higher consumption of vitamin A (Table 2).

[3] In 2003 the minimum monthly wage in Brazil was R. 240 (US$93).

Table 2. Vitamin A consumption in NE Brazil by income groups

Variables		Vitamin A consumption (µg/day)
Income groups	**< ½ of mmw**	190.85
	½ - 1 mmw	304.32
	1 – 2 mmw	362.36
	2 – 3 mmw	425.09
	> 3 mmw	563.99

Source: Author's calculations based on household data from IBGE (2003a).

The survey for this dissertation research was conducted in Pernambuco, a typical state of NE Brazil, which according to the Human Development Index (HDI) ranks fourth among the nine states of this region and 23rd among the 27 states of Brazil. Pernambuco's income index is medium-low (0.632), slightly higher than that of NE Brazil as a whole (0.612), but lower than the national index (0.713). If compared with other countries in the world, this state has the same income index as Morocco. As in other states of NE Brazil, the prevalence rate of VAD in Pernambuco is high: around 20% of the children 5 years of age or younger have less than the minimum level of retinol required. Although the government has been conducting vitamin A campaigns for vulnerable groups, sometimes these programs are insufficient and do not reach all vulnerable groups (Martins *et al.*, 2007).

1.3 Local Relevance of Cassava

Cassava is a staple with worldwide distribution, mainly in the developing countries of Asia, Africa, and Latin America. A fundamental energy source for the poor (FAO, 2004), it grows well in marginal soils and is capable of resisting diseases, drought, and pests. This highly adaptive and vigorous crop is also quite flexible in terms of planting season and is consumed in regions where drought, poverty, and malnutrition prevail (Carneiro, 2006).

Cassava roots are very rich in carbohydrates in the form of starch so their caloric contribution is considerable. They also present high levels of vitamins C, B2, and B6 as well as magnesium and potassium, but hardly any provitamin A. Although cassava

plays an important role in the diets of many developing countries, the study of its nutritional enhancement has only begun recently (Fukuda *et al.*, 2008).

In NE Brazil, cassava ranks second in importance after sugarcane and, among roots and tuber crops, ranks first. Around 950 thousand hectares are planted to cassava in this region, with an annual production of almost 10 million tons (IBGE, 2006). Of this production, Pernambuco accounts for 7%, which is equivalent to 660 thousand tons/year. Based on the 1997 World Bank Living Standards Measurement Study (LSMS), the average consumption of cassava is the same in NE Brazil and Pernambuco (46 kg/year). The main dishes consumed in this state are based on beans, rice, and maize, with a low consumption of fruits and vegetables—important sources of micronutrients. Roots and tubers contribute 10% of total local calorie supply.

Although cassava is an important staple of the Brazilian diet, few studies have been conducted on the preferences of consumers in terms of cassava quality (Borges, Fukuda and Rossetti, 2002; Gonzalez *et al.*, 2005)—information considered important to the outcome of this study because several of the crop's characteristics will change with genetic modification, but others will remain the same.

The International Center for Tropical Agriculture (CIAT) (www.ciat.cgiar.org) and the HarvestPlus Program are developing a cassava with a higher root provitamin A content, using both conventional breeding and biotechnological approaches. In the latter case, scientists work simultaneously with sets of one or three genes of the carotenoid pathway, from plant or bacterial origin, in combination with different regulatory sequences (gene promoters from cassava, potato, yam, or sugar beet). The current biotechnological approach may change in the future with the development of improved strategies. The final product, containing plant-derived genes and regulatory sequences and dark yellow-colored roots, may eventually be released as a GM variety for human consumption.

Traditional table cassava varieties currently consumed in Brazil are mostly sweet varieties[4] with white roots. Except for its color, other root characteristics important to consumers will hopefully not change in the new GM varieties. If they do change, then backcrossing would be necessary to try to partially recover the original genotype. Root

[4] Depending on its levels of cyanogen, cassava can be either sweet or bitter. Sweet or table cassava, also known as *macaxeira*, presents low cyanogen levels and can be consumed directly. On the other hand, bitter cassava or *mandioca* must be processed for consumption, *farinha* and starch being the main subproducts obtained with bitter cassava varieties.

color, however, will remain dark yellow even after backcrossing as this characteristic is directly associated to provitamin A[5].

1.4 GM Crops in Brazil

Brazil has a highly developed agro-industrial sector. In 2007, the country ranked third worldwide in the adoption of GM crops, estimated at 15 million hectares, of which 14.5 million were planted to herbicide-tolerant soybean[6] and 500,000 hectares to Bt cotton. That year Brazil presented the highest absolute growth increase for any country planting GM crops in the world. For almost a decade the introduction of GM crops had suffered significant delays because of legal constraints. Until 2005 there was a court prohibition to plant and market GM crops. However, the Brazilian government is now giving strong political support to biotechnology by increasing the resources available for biotechnological research. Brazil is projected as a world leader in the adoption of GM crops with continued growth in the area planted to soybean, a fast expansion in that planted to Bt cotton, potential opportunities for maize and rice, as well as the enormous potential for GM sugarcane in view of the emerging role of Brazil as world leader and exporter of bioethanol (ISAAA, 2007).

Biotechnology research in Brazil has reached a level that is internationally competitive, and has involved inserting different genes into traditional Brazilian crops. Both private and public research centers have developed a portfolio of GM crops, including virus-resistant papaya, mosaic-resistant bean, virus-resistant potato, insect-resistant cotton, and herbicide-tolerant soybean[7]. However, contrasting with the country's fast rate of scientific development, the approval of commercial GMOs has been relatively slow. GM crops commercialized in Brazil have been either introduced by multinationals, as was the case of soybean, or have been released together with the national public research institute, Embrapa. Different groups of society have accordingly used this situation to fuel the debate against GM crops. National research centers indicated that the costs involved in releasing a GM crop are so high that only multinationals have the capacity to cover them, which places the former in a disadvantageous situation.

[5] Information provided by Paul Chavarriaga, senior scientist of CIAT's Biotechnology Program.
[6] Roundup Ready.
[7] Information provided directly by Embrapa researchers.

Brazil is a mega diverse country and this immense biodiversity demands actions that protect its natural resources. The country also needs to use high technology to be competitive in the world market and to improve the life quality of its citizens—a very important issue in a country with high levels of inequity. Decision makers must carefully and systematically analyze the benefits of new technologies to balance these with the costs implied in risk management.

1.5 Research Objectives and Questions

The overall research objective is to analyze consumer preferences with respect to cassava and to assess public attitudes towards GM provitamin A cassava in Brazil. Such information can help to effectively design biofortification programs targeted at Brazil and other developing countries. In particular, the following research questions are addressed:

1. What is the demand for different cassava attributes in Brazil, and what are the values that consumers place on these attributes?

2. What is the current level of consumer acceptance of second-generation GM foods?

3. What kinds of tradeoffs do consumers make between GM and other cassava attributes?

4. What factors affect the attitudes of the stakeholders and policy makers towards second-generation GM foods?

1.6 Empirical Data Base

To address these research issues, two comprehensive surveys were carried out in Brazil: one with consumer households and the other with other types of stakeholders.

The household survey was conducted in 2006 in the state of Pernambuco in NE Brazil, the poorest region of the country with an average per capita income less than half that of the national average. Pernambuco is one of nine states forming NE Brazil and is considered typical of the region in terms of household income, other development indicators, and cassava consumption (World Bank, 1997). Fifty-three percent of the population in Pernambuco lives below the poverty line of $2 a day (purchasing power

parity), as compared with 54% for the NE region as a whole (IBGE, 2003b)[8]. The state of Pernambuco was selected on purpose to keep data collection manageable. Within the state, the survey concentrated on medium-sized municipalities. Larger cities were excluded because people there do not consume a large amount of fresh cassava. Furthermore, they are not the primary target group for cassava biofortification.

The decision was also made not to focus on purely rural areas, where most households are involved in farming. Although farm households definitely belong to the biofortification target group, many produce cassava themselves so it would have been difficult to separate consumer attitudes from issues related to variety adoption. Although farmer adoption of biofortified varieties is a very important component, this factor was not addressed in this study. Interestingly, however, Heyd (2007) found that farmer adoption of biofortified sweet potatoes in Uganda is largely driven by consumer acceptance, as this is the precondition for being able to market surplus production.

Based on the above, the four medium-sized municipalities of Araripina, Lagoa Grande, Correntes and Itambe were selected as they well represent the socioeconomic, ethnic and dietary spectrum of the state of Pernambuco. Data from the Living Standard Measurement Survey (World Bank, 1997) were used to select these municipalities. In the sampling framework, each of the four municipalities was stratified into zones before randomly selecting the households within the zones. The overall sample comprises 414 households. Due to the specific focus, the sample is not representative of the entire population of NE Brazil, but is representative of households in medium-sized municipalities of NE Brazil and, accordingly, of the region's fresh cassava market consumers.

The 414 households in the four municipalities were interviewed face to face, based on a structured questionnaire that was carefully designed and pre-tested (see Annex). The interviews were carried out in Portuguese by a locally hired team of four female enumerators that was permanently accompanied by the author so that ambiguities could be clarified on the spot. The enumerators were familiar with health issues in general and VAD in particular, as they had previously conducted surveys for the governmental health service and also received training specific to this study. Interviews were always conducted with the person responsible for deciding what food was purchased. The structured questionnaire covered general household characteristics

[8] Poverty rate for Brazil as a whole is 36%.

and different consumer perceptions, and also contained modules that aimed to collect contingent valuation and choice modeling data. In general, people were very willing to answer the questions; however, 7% of the selected households refused to participate and had to be replaced by other households selected at random.

The stakeholder survey was carried out in August 2008. First, an inventory of stakeholders involved in issues related to GM crops was compiled using the CNTBio database.[9] Information provided by Brazilian experts in GMOs was used to complement the database. Ninety-eight of the 200 stakeholders identified in the inventory were randomly selected for the survey. A structured questionnaire in Portuguese (see Annex) was used; 38 stakeholders were interviewed face to face; 20 questionnaires were answered by e-mail; and the remaining 40 were interviewed by phone. The sample comprised stakeholders from local and international NGOs; the industry, research, and academic sectors; and government agencies throughout the country.

The questions covered stakeholder characteristics; perceptions about GM crops for food in general and the specific case of a GM cassava with enhanced provitamin A content; and the type and frequency of stakeholder relationships. Respondents were encouraged to share their individual viewpoints.

1.7 Structure of the Dissertation

These research questions mentioned above are addressed within three articles in the order mentioned. The first article, titled "Consumer Preferences for Table Cassava Characteristics in Pernambuco, Brazil", analyzes the demand for different cassava attributes and applies the hedonic price method to estimate the values that consumers give to specific attributes. The paper is an important input for biofortification programs because some attributes or characteristics are related with the GM cassava, for example the change in color.

The second research article, titled "Consumer Acceptance of Second Generation GM Foods: The Case of Biofortified Cassava in the Northeast of Brazil", builds on the hypothesis 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. This hypothesis is tested by using contingent valuation techniques and estimating consumers' willingness to pay. Furthermore, we are

[9] CNTBio is the technical commission responsible for biosafety issues in Brazil (ww.ctnbio.gov.br).

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. The trade-offs between different cassava attributes are examined with the help of a choice modeling 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 third article, titled "Stakeholder Positions Toward GM Food: The Case of Vitamin A Biofortified Cassava in Brazil", analyzes what factors affect stakeholder positions towards GM foods in Brazil in general and towards GM provitamin A cassava in particular. The stakeholder survey data are analyzed with different statistical techniques. Understanding the broader public attitudes about GM crops in a country and their determinants can be crucial for research programs, as experiences from around the world show that stakeholder positions can significantly influence the efficiency of regulatory approaches and the success of new technology releases.

The dissertation closes with a conclusions chapter, in which the main findings are summarized and synthesized. Broader research and policy implications are discussed.

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CHAPTER II

CONSUMER PREFERENCES FOR TABLE CASSAVA CHARACTERISTICS IN PERNAMBUCO, BRAZIL

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Abstract

Cassava is a major source of carbohydrate for populations in the tropics; however, there is little information about the preferences of consumers toward the quality characteristics of this crop. This paper analyzes the demand for different cassava attributes, and applies the hedonic price method to estimate the values that consumers give to implicit attributes of cassava. The results show that ease of peeling, time of cooking and texture of cassava are the most important characteristics consumers consider when purchasing and consuming cassava. Cassava varieties, root size, ease of peeling and location of the market are relevant attributes in price determination.

Keywords: cassava, consumer preferences, hedonic price, Pernambuco, Brazil

Resumo

A mandioca-de mesa (macaxeira ou aipim) é uma das principais fontes de carboidrato das populações nos trópicos. No entanto, há pouca informação sobre as preferências dos consumidores em relação às características de qualidade deste cultivo. Este artigo analisa a demanda de diferentes atributos da mandioca de mesa e aplica o método dos preços hedônicos para estimar o valor que os consumidores dão aos atributos implícitos deste tubérculo. Os resultados mostram que a facilidade de descascamento, o tempo de cozimento e a textura da mandioca de mesa são as características mais importantes para os consumidores quando a compram e consomem. O tipo de variedades, o tamanho da raiz, a facilidade de descascamento e a localização do mercado são atributos relevantes na determinação dos preços.

Palavras – chave: mandioca mansa, preferências do consumidor, preços hedônicos, Nordeste do Brasil

JEL: Q13, D12

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a root crop from tropical America. It is the fourth most important food staple produced in the tropics, with a global production of 228 million tons (FAOSTAT, 2008) and it is a major source of carbohydrate for populations in the humid tropics, around 700 million people obtain more than 500 calories per day from cassava consumption (HARVESTPLUS, 2008). It is in Sub-Saharan Africa where the per capita consumption is the highest (101 kg/year) (FAOSTAT, 2008). In Latin America and the Caribbean the consumption per capita is lower (21kg/year) however, in Brazil cassava continues to be a principle staple food and average per capita consumption is 41 kg/day (FAOSTAT, 2008).

Cassava is usually considered a subsistence crop, grown and eaten by the poor. However, recent studies in Brazil suggest that because of migration from rural to urban zones and price seasonality among other factors; many people purchase their cassava, even if they also produce (SOUZA, FARIAS, MATTOS, *et al.*, 2006). This means that attention must be paid to consumer and market characteristics as well as to production characteristics such as yield and disease resistance, which have previously been a major focus on breeder attention (CIAT, 2007).

There are many food products derived from cassava. The traditional categories according to the root type are: table or sweet cassava and industrial or bitter cassava. In Brazil, most table cassava is distributed for direct consumption as fresh cassava called *macaxeira or aipim. Farinha* (a toasted flour) and starches are the main sub products of industrial cassava. Several studies have looked at processed products of cassava, especially in *farinha* and starch production and commercialization (CAPRILES, SOARES and AREAS, 2007; SOUZA, FARIAS, MATTOS, *et al.*, 2006); however, there are very few studies about fresh cassava. Due to cassava's importance in the agricultural market and diet of the poor people in the Northeast (NE) of Brazil, the objective of this paper is to help fill the knowledge gap about consumer preferences for fresh cassava. First, using a hedonic price analysis, we attempt to measure the consumer's implicit price of cassava characteristics. This approach postulates that the price of goods is a function of the quality characteristics of the product. To complement this analysis, using logit models we look at what consumer say about their preferences for specific cassava attributes. These results should be useful for producers and sellers of fresh cassava since they show to what extent quality differentials are reflected in price. They could also be useful for researchers in their decisions about characteristics to consider in crop improvement programs. The paper is organized as follows.

Section 2 and 3 describe the background and the theoretical model employed in the analyses. Section 4 presents the data and describes the variables used in the analysis. The empirical results are reported and discussed in the Section 5. Finally the conclusions are presented in Section 6.

2. Background

2.1 Crop Characteristics

Historically cassava has played a fundamental role in Brazil as source of carbohydrates for human consumption and as a supply of employment and income in poorer rural areas especially in the Northeast (NE). Cassava varieties are often categorized as either "sweet" (*macaxeira or aipim*) or "bitter" (*mandioca*[1]), reflecting the absence or presence, respectively, of toxic levels of cyanogenic glucosidesis. The former can be consumed directly after peeling and either boiling, baking or frying, while the latter needs additional processing such as fermentation or drying. The bitter varieties of cassava are used for industrial uses (OSPINA and CEBALLOS, 2002).

In optimal conditions[2] cassava requires at least 10 months of warm weather to produce a crop. It is traditionally grown in a savanna climate, but can be grown in extremes of rainfall (O'HAIR, 1995). Certain inherent characteristics have made cassava an important crop in Brazil: it has very high productivity per unit land area; it is well adapted to adverse climatic and soil conditions; it has no fixed planting date or time of harvest; and its rarely fails as a crop.

2.2 Price

Two characteristics strongly influence the price of fresh cassava—perishability and competition with other derivate cassava products. These factors plus a market composed of small producers with low technology adoption, low degree of organization and lack of access to information lead to significant fluctuations in prices. In Brazil, studies reveled that cassava has a demand elasticity less than 1; CARDOSO AND SOUZA (1999) showed some elasticity coefficients: -0,02 (1970), -0,02 (1975) and –0,03 (1975). In this condition incentives for more production could be perverse and harmful for producers, leading to reductions in prices and, by extension, in producer incomes. For these reasons it is important to work to add value

[1] Popular Portuguese name.
[2] The production cycle is the same for both sweet and bitter varieties.

to fresh cassava, focusing in improve the attributes, which differentiate the product in markets.

3. Theoretical Model

Much work has been done on the impact of quality characteristics on price of agricultural products in developed countries (WAHL, SHI, and MITTELHAMMER, 1995; BOWMAN and ETHRIDG, 1992). However, few empirical studies have been conducted to quantify the value of quality characteristics of traditional crops in developing countries (UNNEVEHR, 1986; SAMIKWA, BRORSEN and SANDERS, 1998; DALTON, 2004; EDMEADES, 2006). This method presumes that the price of a marketed good is related to its characteristics. Therefore the observed product price is constructed by the attributes of the product (WILLIAMS, SPYCHER and OKIKE, 2003). The marginal implicit value of output characteristics can be derived from a hedonic price function that traces the behavior of consumers and producers of differentiated products (EDMEADES, 2006).

The buyer's bid function is derived through utility maximization subject to an expenditure constraint, and it can be represented by the utility function.

$$\mu = \mu(z_1, z_2, ..., z_m; Y, \alpha) \quad (1)$$

Where, μ(.) is the buyer's bid function for the product in the market, z is a vector of the characteristics of the good, Y is the buyer's total expenditure and α is a vector of observed and unobserved parameters, which characterize the preferences of the consumer. The first partial derivative of the bid function with respect to an individual characteristic depict the buyer's willingness to pay for an additional unit of the characteristic (CAREW, 2000).

On the supply side, the seller's offer function can be specified as:

$$\varphi = \varphi\ (z_1, z_2, ...z_m; N, \gamma) \quad (2)$$

Where φ (.) is the seller's offer function, N is the output quantity of good produced by the seller with characteristic specification *z*, and γ is a vector of prices and production technologies. The offer function is defined as the minimum price that the seller is willing to accept for supplying N units of good having characteristic levels z. The first partial derivative of the offer function with respect to an individual characteristic reveals the seller's marginal implicit valuation for providing other unit of that characteristic.

In the market, the sales occur when both, buyer and seller agree on the price of a particular product with a specific set of characteristics. The intersection point between the

buyer's bid curve and the seller's offer curve for the characteristics represents this situation. Simultaneously, the intersection point also represents the buyer's and seller's marginal implicit bid and offer, respectively (WAHL, SHI, and MITTELHAMMER, 1995).

Finally, the hedonic price function is estimated by regressing the equilibrium price of products on the characteristics of the product. It can be expressed as:

$$P(z) = f(z_1, z_2, ..., z_m) \quad (3)$$

Where P (z) is the price of a good and z is a vector of quality characteristics of the good.

4. Methodology

The NE suffers the highest levels of poverty and underdevelopment in Brazil. In this region, skewed land distribution and semi-arid climate are among the factors that contribute to the region's high relative levels of infant mortality, absolute poverty, unemployment, underemployment, illiteracy, lack of access to basic services and malnutrition (OSPINA and CEBALLOS, 2002). Pernambuco, the focus of this study, is a typical state in the NE Brazil. In terms of population it is second after Bahia with an estimated population of 8.5 million in 2007 (IBGE, 2007). Over 85% of the area of Pernambuco falls into the category of semi-arid (less than 600 mm rainfall in a year). This state is the fourth largest producer of cassava in the NE of Brazil, approximately 660 thousand ton/year. However it has the second highest per capita cassava consumption rates, 125gr/day per capita after Paraiba (WORLD BANK, 1997). In semiarid Pernambuco, low and variable rainfall makes cassava practically the only staple food crop option for farmers, and cassava consequently constitutes the main food source, especially for low-income people.

For analyzing consumer preferences we conducted a survey in the state of Pernambuco during the end of 2006 and beginning of 2007. The interview-based survey was carried out in urban areas of four medium-sized municipalities with high production (in their rural areas) and consumption of cassava. These municipalities represent the two major geographic zone of this state: a. Semiarid (Agreste and Sertao) and Coastal (Zona da Mata and part of Agreste). We took two municipalities from semiarid and two from coastal. They are typical cassava production zones with different varieties of sweet cassava in the local markets. A stratified random sampling method was employed: households were selected

randomly after stratifying each city into zones by income[3]. A sample comprising 414 respondents was achieved. However, 473 observations were achieved because there are more than one variety of cassava purchase for some households. Personal interviews were conducted in the people's home with the person in charge of purchasing the household food.

4.1 Variables and empirical model

In this study we only refer to sweet fresh cassava varieties (*macaxeira or aipim*), for direct consumption. We focused on this type of varieties because they are very important in the diet of poor people. As mentioned earlier, very few studies have addressed looked at the market for this crop –a market that could potentially increase due to Brazil's trend toward urbanization.

Based on a pilot study and on expert opinion of cassava researchers, we identified possible quality characteristics that consumers might consider when buying and consuming sweet cassava. Specifically, we looked at the following characteristics:

a. Colour: We differentiate the peel colour from the flesh colour. In this region consumers normally find in the market cassava with three peel colours: white, pink and yellow. The flesh colour of pink and white peel varieties is white while yellow varieties have a same peel and flesh colour. In some cases, names of the varieties consumed are associated with these colours.

b. Time of cooking: for consumers a good cassava takes around 15 – 20 minutes for cooking after boiling. In the pressure cooker, it should only take 5 minutes.

c. Taste: Some cassava varieties are considered sweet, while others have a more neutral flavor.

d. Texture: This refers to the level of hardness in chewing the cassava. The options in this study are mush or mealy.

e. Easy of peeling: It is very common when people buy cassava to take a little portion to tell if peeling is easy or not. Ease of peeling indicates cassava good quality.

f. Fiber: Cassava is considered fibrous when some strands are difficult to chew. While this is an undesirable characteristic, it is a very difficult one to detect at visually.

g. Size: This refers to the thickness (diameter) of the root. We divided them into fine (18 – 40 mm) medium (41- 55 mm) and thick (>55mm).

[3] We interviewed people of medium and low income. However, it is important to say that three of the four municipalities do not have people with high income. In these cases we basically included all the urban area of the municipality.

We also collected information on the price of cassava by variety, where the cassava was purchased, and quantity and frequency of cassava consumption in the household, along with demographic information (Table 1).

Excluding the influence of market forces that can affect general price levels, an empirical model for fresh cassava can be specified as:

$$\text{Price/kg} = \begin{aligned} &\beta_0 + \beta_1 Colour + \beta_2 Size + \beta_3 Taste + \beta_4 Fiber + \beta_5 Texture \\ &\beta_6 TIME + \beta_7 Easepeel + \beta_8 Location + \varepsilon_I \end{aligned}$$

Since the model includes only dummy variables to measure quality characteristics, except *time of cooking*, the estimated coefficients determine the ranking pattern of each attribute on price.

5. Results

Most of the interviewees were female (93%) probably because they are the people who did the majority of shopping in the household (Table 1). Fifty five percent only have elementary education and around a 10% were below the poverty line of US 1 a day per capita. The average number of people in the household is 4.4, and 67% of households have children under 5 years. Approximately, 50% of respondents are housewives and 9% have a formal employment, mostly in the public sector. Around 80% of the respondents buy their cassava in the traditional or local markets, a pattern that is consistent across the two regions. In the semiarid region, the percentage of people who buy the crop in supermarkets (10%) is higher than in the coastal region (only 1%), where sellers who go door to door commonly sell fresh cassava.

Households consumed cassava on average 2.84 times per week, with slightly more frequent consumption in the semiarid than the coastal zones (Table 1). This number shows the importance of cassava as basic staples; however it is also shows that people do not consume it every day as they do with some staples such as rice in Asia or maize in East Africa and Central America. The average quantity of cassava eaten per meal in a household is 335g. Finally, the average of amount spent on cassava per week in the household is R.$ 1.84/kg, which is approximately 2% of total food expenditure.

Regarding the preferences, respondents were asked to rank, in order of importance, the three main characteristics they consider when buying or eating cassava. The results show that *ease of peeling* (29%) is the most important characteristic for consumers. One possible explanation is that this characteristic is easy to test, and people consider it an indicator not

only of amount of work involved in peeling but also of other quality characteristics. After *ease of peeling*, *time of cooking* (28%) is another important characteristics for consumers, followed distantly by *texture* (16%) and then *colour* (11%). *Price* has the lowest place in the consumer ranking, which is consistent with the price inelasticity of cassava.

We have a special interest in colour preferences because there are cassava varieties with other colours different from the commonly white that could be introduced to markets as a high value product (HARVESTPLUS, 2008). The consumers of the areas that we study distinguish between two colours: white and yellow. The most popular varieties have the former colour. The latter colour is better known in the interior (semiarid region) of the country, where people called these types of varieties *manteguinha*, which means butter in Portuguese. In the semiarid region people consume more yellow cassava than coastal, 50% versus 17%. We asked about reasons why consumers do not purchase or consume yellow varieties. In the semiarid, they mentioned that *manteguinha* does not cook very well or takes more time than white cassava (12%) for cooking[4]. On the coast, the main reasons are that they have never tasted, eaten or seen it (75%).

5.1 Hedonic price

In the literature, there is some debate regarding the most appropriate functional form to use to estimate the hedonic function. In general, the theory underlying the approach does not provide much guidance about which of these functional forms is most appropriate. ROSEN's (1974) work suggests that hedonic function not be linear (CROPPER, DECK and MCCONNELL, 1988). In this study we used the Akaike Information Criterion (AIC)[5] to select the functional form of hedonic price model; we tested linear, semilog, double-log, quadratic, and a Box-Cox transformation technique. According to the AIC test, linear and semilog were the best functional forms. However, because semilog form has additional properties, it was selected as useful choice for hedonic price model[6]. Price flexibilities—defined as the percentage of change in the price with respect to a 1% increase in the characteristic—were estimated to measure sensitivities. For discrete characteristics, the price

[4] The results suggest that it is a wrong consumer perception; we did not find a significant difference in time cooking between white or yellow cassava (12,5 minutes).

[5] This criterion minimized over choices of the number of parameters (x) in the model to form a tradeoff between the fit of the model and the model's complexity. Given a data set, competing models may be ranked according to their AIC, with the one having the lowest AIC being the best (EDMEADES, 2006).

[6] First, the implicit value of crop characteristics may be a function not only the level of the characteristic itself, but also a function of the levels of other characteristics embodied in the crop. Semilog hedonic model are consistent with this observation (WAHL, SHI, and MITTELHAMMER, 1995). Second, it is more useful to calculate results expressed in price flexibilities.

flexibility is defined as the percentage change in the price due to the presence of the characteristic relative to its absence. Given the semilog specification of the hedonic price model, marginal value has to be estimated[7]; it can be expressed as $p = (e^{\beta_i}) - 1$, where p is calculated at mean of continuous variables and at zero for discrete characteristics.

Parameters obtained via estimation of semilog model, marginal value and price flexibilities are reported in Table 2. In general, estimated parameters were consistent with hypothesized signs, and the F test is statistically significant. The results of the model indicate that varieties with yellow peel colour have a higher value to consumers than pink, with a price premium of R.0.09/kg. The price flexibility of yellow varieties shows that a presence of this characteristic, holding all else constant, increases by 11% the cassava price. Unsurprisingly, people pay for bigger sizes, if cassava size decrease from thick size to medium or fine, respectively, the cassava price would reduce by 7.4 and 13% respectively. If marginal cost of changing from pink to yellow peel varieties, or of producing bigger cassava roots were less than R.0.08/kg and R.0.09/kg respectively, these results suggest that it would be beneficial for the producer to do so. Additionally, cost of production does not depend on the type of cassava variety; it is more related with the production system. Therefore producing cassavas with characteristics more attractive to the market should not imply an increase in cost. The great marginal gain for producer, however, may be associated with the location. In coastal areas cassava price is lower than in the semiarid regions. The price difference it is around R.0.39/kg. Regarding to price flexibilities of dummy location variables (semiarid), the coefficient reported is positive; holding all else constant, cassava price in the semiarid would increase by 50%. Nevertheless, it could be not profitable for fresh cassava producers in coastal region to distribute their production in the semiarid due to the perishability and the high costs of transportation and refrigeration.

Unexpectedly *ease of peeling* has a negative coefficient, which could be attributed to the low percentage (3.8%) of consumers of *hard-to-peel* cassava, who pay a significantly higher price, as compared with consumers of *easy-to-peel* cassava. When the characteristics of consumers of *hard-to-peel* cassava were analyzed, results indicated that many of them produced their own cassava or purchased cassava in supermarkets or at their door, which could mean that these consumers pay a higher price for this cassava because they assume they are purchasing a quality product. However, the quality of the cassava is not always as

[7] Marginal value is defined as the change in the price with respect to one unit increase in the characteristics from its mean value. In the case of discrete variables, it depends on the presence or absence of the characteristics. (WAHL, SHI and MITTELHAMMER, 1995).

expected. Other attributes such as *texture, taste, quantity of fibers* and *time of cooking* are statistically unimportant in terms of their influence on price. This may be due to the fact that these characteristics can only be known after cassava has been boiled and consumed. This suggests that complementary research needs to be done using other methodologies such as sensorial techniques, for example, in order to know the real economic importance of these characteristics.[8]

5.2 Logit model: Consumer preferences

We estimated a logit model for each characteristic to assess the influence of socioeconomic and demographic characteristics of consumers on cassava preferences. Specific factors considered included sex, age, education, monthly household income, region (semiarid and coastal), a dummy variable for purchase and for own production[9] and kilograms of fresh cassava consumed in the household per meal. For each attribute, the dependent variable was one for households that ranked that attribute most important. The estimated results show that not all the characteristics had statistically significant models. *Price*, *colour* of the cassava, amount of *fibers*, and other characteristics had less than 10 % of people ranking them as most important. However, we obtained interesting results with *time of cooking*, *texture*, *taste* and *ease of peeling* (Table 3).

Ease of peeling is more important for women than for men, which make sense because in this zone women not only purchase but also prepare the cassava. Men, on the other hand, place more importance on *taste*, a significant percentage (70%) prefer sweet cassava toward 13% of women, who prefer a neutral taste.

Some studies show that there are significant differences between consumer preferences among regions (SOUZA, FARIAS, MATTOS, *et al.*, 2006), and the results of the study confirm this. While *taste* is very important in the semiarid region, *texture* is determinant in the coastal region; for example, consumers in the former region would prefer the taste of sweet cassava while those in the latter region would prefer cassava with a mush texture. For producers and researchers these findings are very important to know which varieties should be produced and oriented to which regional market.

In the literature, cassava is considered an inferior good, meaning that at lower levels of income more quantity of cassava consumed in households. The results of this study

[8] There are some studies to attempt relate the sensory qualities of cassava roots to their physicochemical properties (PADONOU, MESTRES, and MATHURIN, 2005; BELÉIA, PRUDENCIO-FERREIRA, YAMASHITA et al., 2004), however they did not develop a economic valuation.

[9] In some cases a person could be producer and buyer of cassava at the same time.

support that contention; households in the study with less income consume more grams of cassava than household with more incomes (362 gr./meal vs. 249gr/meal). The propensity to prefer *time of cooking* is also negatively influenced by income. Household with higher levels of income in the sample have lower probability of select *time of cooking* as the most important characteristics for buying and consuming cassava, which might reflect that they are less concerned with the fuel-related costs associated with longer cooking.[10]. Levels of education have significant effects on which characteristics are more important. *Time of cooking* is more important for consumers with a university education as compared with consumers with only elementary schooling, who in turn prefer *ease of peeling*. The preference of the former could be attributed to the less time they have to dedicate to household chores. Households with higher consumption of cassava per meal likely take more into account *texture* and *taste* of this crop at purchase or consumption moment. *Time of cooking* it is less important for them. Finally, *ease of peeling* is an important characteristic for both consumers who have their own production and also for those who purchase cassava. These results are consistent with the raking of most important characteristics that consumer consider when buying cassava. In sum, the empirical applications of the qualitative model offer valuable insights into the factors that influence decisions regarding the desirable characteristics for consumers.

6. Conclusions

This paper evaluates the consumer preferences for cassava in Pernambuco, a state in NE Brazil. The aim of the paper was to fill an information gap about consumer preferences for quality characteristics in order to help producers and researchers to develop varieties more attractive for the markets. Knowledge about implicit values of quality characteristics indicates which attributes should be focused on and which characteristics could be allowed to vary. The empirical results presented above indicate that some attributes are very important when people buy cassava such as *ease of peeling,* or *time of cooking* and *texture* for cassava consumption. The estimated results in the hedonic model in terms of prices show a big difference between semiarid and coastal region, also among yellow and pink varieties. The price of yellow cassava is higher than other varieties; but its market is smaller because it is only known and preferred in the semiarid region. Fresh cassava with larger size has a premium. According to researchers the size of cassava depends on production system and

[10] The average per capita income is 166 reais per month (US $78). Ten percent of the households are extremely poor; many more can be classified as moderately poor.

environmental characteristics. Therefore producers have to take in account those variables in order to obtain a desirable size cassava root.

Consumer preferences toward characteristics such as *texture* and *taste* are also highly influenced by region. This result suggests that producers in semiarid should grow a meal fresh cassava, with a sweet taste; while producers in coastal could have good market opportunities with a mush cassava, with neutral taste. Although price is relatively unimportant in the consumers' ranking of attributes, it is truly relevant for producers. Because of inelasticity of cassava demand, it is very important to add value to this crop, to avoid driving down incomes in the long term.

Finally, complementary studies should be carried out including sensorial techniques of cassava characteristics related with an economic valuation. It is important to deepen the market study of the basic staple crops. This type of research could be conducted for other crops as potatoes or beans to guide producers and researchers to varieties which are most valued by consumer.

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Table 1: **Descriptive statistics**

Variables		**Semiarid**	**Coastal**	**Total**
Female respondent, dummy (%)		90.48	96.17	93.00**
Age of respondent (years)		39.43 (14.14)	41.31 (13.63)	40.48 (13.93)
Size of household (people)		4.45 (1.99)	4.33 (1.69)	4.40 (1.87)
Education of respondents (%)	**No formal education**	16.45	15.30	15.94
	Elementary school (1 –6 years)	53.55	57.14	55.56
	High school (7 – 11 years)	22.51	26.78	24.40
	University	3.90	4.37	4.11
Monthly household income (Reais)		429.45 (207.3)	395.76 (192.4)	414.55 * (201.3)
Consumption of cassava in the household	**Price (Reais/kg)**	.91 (.29)	.59 (.18)	.77 *** (.29)
	Cassava consumption (kg/meal)	.391 (0.05)	.290 (0.06)	.335 *** (.05)
	# times eat cassava/ week	3.00 (1.35)	2.63 (1.32)	2.84 *** (1.35)
	Amount spend/week	2.09 (1.36)	1.52 (.77)	1.84 *** (1.17)
	Cassava producer, dummy (%)	16.45	15.85	16.18

N:414; *,**,*** The difference between semiarid and coastal is statistically significant at the 0.10, 0.05 and 0.01 level, respectively

Table 2. **Hedonic price of cassava**

Variables		**Coef.**	**Price flexibilities**	**Marginal Value**
Colour (ref. pink)	**white**	-.018 (.029)	-0.018	-0.014
	yellow	.107 ** (.047)	0.113	0.088
Size (ref. thick)	**fine**	-.140 *** (.050)	-0.131	-0.102
	medium	-.077 ** (.035)	-0.074	-0.058
Taste (ref. neutral)	**sweet**	.041 (.032)	0.042	0.033
Fibers (ref. low)	**much**	.029 (.064)	0.029	0.023
Texture (ref. mealy)	**mush**	-.021 (.031)	-0.021	-0.016
Ease of peeling (ref. hard of peeling)		-.136 ** (0.67)	-0.127	-0.099
Time of cooking (min)		-.003 (0.003)	-0.038	-0.002
Location (semiarid)		.408 *** (.030)	0.504	0.392
Intercept		-.336*** (.090)		
F(10, 462)		30.20***		
R-squared		40%		

N:473; *,**,*** Statistically significant at the 0.10, 0.05 and 0.01 level, respectively

Table 3: **Socioeconomic factors explaining cassava preferences (logit models)**

Variables		Time of cooking		Texture		Taste		Ease peeling	
		Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE.
Female respondent		.03	.44	.63	1.06	-1.66***	.62	.95**	.47
Age (years)		.01	.01	-.01	.02	.01	.021	.01	01
Education Elementary	**No education**	-.31	.33	.071	.59	.34	.78	.08	.31
	High school	-.11	.28	.66	.41	.94	.62	-.10	.27
	University	1.92***	.61	-.34	1.09	b.		-1.47**	.70
Household income (R.)		-.00***	.00	.00	.00	.00	.00	.00**	.00
Kg/meal/per capita		-8.92***	2.45	5.54*	2.94	6.99*	1.08	2.20	1.97
Own production, dummy		-.68	.50	a.		a.		1.10***	.43
Cassava buyers, dummy		-.29	.61	-.54	.54	.23	1.08	1.29**	.54
Semiarid, dummy		-.28	.23	-1.36***	.41	1.01*	.61	.28	.22
Intercept		1.15	.89	-2.41*	1.37	-4.36***	1.65	-3.81***	.87
Log likelihood		-247.90		-114.27		-61.93		-264.31	
Chi-squared		37.72***		25.37***		16.53**		24.69***	

N:414; *,**,*** Statistically significant at the 0.10, 0.05 and 0.01 level, respectively
a. Variable dropped because there are not people that simultaneously are producer and buyer.
b. Variable education-university = 0 predicts failure perfectly; it was dropped and 17 observations not used.

CHAPTER III

CONSUMER ACCEPTANCE OF SECOND GENERATION OF 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 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 9.5 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 consumers perceive that they usually require longer time of cooking (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 time of cooking).

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 understands technology acceptance levels and preferences among the target population.[11]

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 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 choices 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).[12] 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.[13] 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 different ways. We used a double-bounded dichotomous choice format, which is more

[11] 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.

[12] 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.

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

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).[14] 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 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 is denoted z_{ij}. The utility of each element in *C* for each individual is represented as:

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

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:

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

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

[14] 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.

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 (*farinha*) is used all the year around (Gonzalez *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).[15] 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.

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

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

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.[16] 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

[16] 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.

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.[17] 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 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.

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

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.[18] 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 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.[19] 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 mean WTP. Loureiro and Bugbee (2005) found that

[18] 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.

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

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,[20] 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 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

[20] 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.

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	156.10	199.31	154.25	165.37	166.09
(reais)	(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,	54.19	57.89	57.89	53.27	55.31
dummy (%)					
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.

CHAPTER IV

STAKEHOLDER POSITIONS TOWARD GM FOOD: THE CASE OF VITAMIN A BIOFORTIFIED CASSAVA IN BRAZIL

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Abstract

This paper examines the factors that affect stakeholders' positions toward genetically modified (GM) crops in Brazil, both in general and in the case of a GM cassava in particular. Perceptions about the benefits of the 'second-generation' GM crops that have direct benefits for consumer are analyzed, and the tradeoffs that stakeholders make between the advantages of GM crops in terms of food quality and their potential risks in other areas as the environment are assessed. Using the Multiple Correspondence Analysis and cluster approaches, it was revealed that most of the stakeholders have positive attitudes toward GM crops. A high percentage agrees with the introduction of a GM cassava; however a significant number of stakeholders are against this introduction because Brazil has other nutritional sources to combat Vitamin A deficiency. In addition, the country is a centre of origin and diversity for cassava, which increases potential environmental risk associated with GMO release.

Keywords: *Brazil, cassava, centre of origin, GM food, Multiple Correspondence Analyses, stakeholder positions*

EconLit classification codes

O320 Management of Technological Innovation and R&D

Q160 Agricultural R&D; Agricultural Technology; Agricultural Extension Services

Q180 Agricultural Policy; Food Policy

1. Introduction

Governments and civil society recognize that modern biotechnology has enormous potential, for human health as well as for environmental and economic development. The 'first generation' of genetically modified organisms (GMOs) in agriculture allow farmers to increase yields and reduce the use of agricultural chemicals. The 'second-generation' of genetically modified (GM) foods is probably most interesting for consumers because these are products with enhanced quality attributes or nutritional benefits (Onyango and Nayga, 2004).

The first generation of GMOs experienced fast adoption rates in the United States and some developing countries such as Argentina (Qaim and Zilberman, 2003). However, GM food products have faced mixed regulatory and public acceptance because of the multiple concerns over the human and environmental safety of these technologies. The vast majority of studies on consumer attitudes and the acceptance of GM foods have been conducted in developed countries, where most of the controversy over GM foods originated.

Because they continue struggling to achieve food security, developing countries may stand to benefit most from agricultural biotechnology. However, little is known about how the stakeholders in developing countries would respond to the second generation of GM food (Gonzalez, Johnson and Qaim, 2009; Dawe and Unnevehr, 2007; Juma, Paarlberg, Pray, and Unnevehr, 2007). What Paarlberg (2003) observed is that developing countries have become a battleground between proponents and opponents of GMOs with governments of developed countries and non-government organizations (NGOs) trying to influence the developing countries' position toward biotechnology. Aerni (2005) and Bernauer (2006) found support for the Paarlberg argument when they concluded that in developing countries local NGOs have adopted a political agenda against or in favor of agricultural biotechnology depending on their foreign donors, normally international NGOs or organizations. To avoid ineffective political polarization he suggests increasing the participation of local academia in the public debate since these institutions have a potential domestic leadership role especially regarding agricultural biotechnology. People still trust academia more than other stakeholders, therefore they can use this political resource to focus the biotechnology debate on domestic problems and curb the foreign interference. These studies suggest that much work needs to be done, starting with understanding the true

internal position of developing countries, which is decisive for future of these technologies (Juma et al., 2007).

Following the model of Aerni and Bernauer (2006) study, this paper examines which factors affect stakeholder positions toward GM food crops in Brazil, with special attention to the case of a new genetically modified cassava biofortified with provitamin A. Perceptions about the benefits of the so-called 'second-generation' GM crops that have direct benefits for consumer are analyzed, and the tradeoffs that stakeholders make between the advantages of GM crops in terms of food quality and their potential risks in other areas such as the environment are assessed. The environmental question is especially relevant in this case because Brazil is the centre of origin and genetic diversity for cassava (Nassar, 1978).

The paper begins with a brief account of the introduction of GMOs in Brazil and the current political situation with respect to this topic. The second section explains the framework and methodology used. Section three identifies the stakeholders in Brazilian biotechnology and characterizes their positions towards GM food and the possible introduction of GM cassava biofortified with more provitamin A. Additionally in this section, there is an analyzes of the factors that affect the stakeholder positions, and last section summarizes and concludes with recommendations for policy.

2. GMOs in Brazil

The GMO policy in Brazil has been ambiguous from its beginnings. Since 1995 this country has attempted to develop biosafety legislation and to establish a structure for monitoring the introduction of GMOs. The Law 8974 and Decree 1752/1995 created the National Biosafety Committee (CTNBio), a governmental agency responsible for developing guidelines on GMO use in Brazil. The national policy permitted research on GMOs and allowed commercial products that contained GM material, but prohibited commercial production of GM crops (Oda and Soares, 2000). In 1998, Monsanto requested and received from CTNBio permission to market the Roundup Ready soybean. After that, an injunction against Monsanto and CTNBio was filed by Greenpeace and the Brazilian consumer's institute (IDEC), on the basis that this crop could be harmful for the environment. In 2000, the court ruled to prohibit cultivation and commercialization of the GM soybean.

During October-November 1999 a report suggested that 2 million hectares were planted with illegal seed bought in Argentina (Sampaio, 1999). For this reason, although

there were moratorium laws prohibiting the commercial use of GMOs until 2005, the government is currently offering an amnesty to soy farmers who had illegally planted GM soy during the 2003 - 2005 ban (Neto, 2003).

In 2005, Brazil released the controversial Biosseguranca Law. This law permits production, transportation, import, export, storage, transformation, research and trade of GMOs. There were also some important changes regarding the CTNBio. Under the old legislation, this institution was a part of the Presidency; currently it belongs to the Ministry of Science and Technology. Organizations opposed to GMOs interpreted this change as a loss of independence. In addition, the scope of CTNBio was extended beyond release of GMOs into the environment to also include topics such as health and social issues related to GMOs.

Despite the lack of a clear policy during the period 1999-2005, the industrial sector and the national research establishment in Brazil were interested in developing biotechnology products. EMBRAPA, the Brazilian agricultural research center, worked alone or together with national and multinational companies to develop a wide range of GM crops including corn, soybean, cotton, eucalyptus, sugarcane, tobacco, potatoes, sweet corn, and papaya (Portugal, Sampaio, Contini, and Avila, 2001). Because of the moratorium, however, some of that research was lost. Currently there are few commercial, foreign or domestic GM crops in Brazil, mainly soy, cotton and corn.

3. Framework and Methodology

The development of GM crops has been accompanied by studies about public or consumer acceptance, using a range of different methodological approaches. Bredahl, Grunert and Frewer (1998) reviewed three models that seek to explain consumer attitudes, buying behavior, and attitude change regarding genetically engineered food products. The first model, built on Fishbein's multi-attribute attitude model, suggests that attitudes towards genetic engineering are determined by beliefs, either about production processes or perceived quality of final products. Demographic characteristics and other factors are assumed to influence attitudes only indirectly.

Many studies based on this model have been conducted with different, GM food innovations in different countries and consumer contexts. Some studies conclude that public trust is a decisive factor in determining consumer attitudes (Barling et al., 1999; House, Morrow, Lusk and Moore, 2001), while in other research suggests that consumer attitudes are the results of risk-benefit perceptions explains observed consumer attitudes

(Boecker, Nocella, Bertazzoli and Lucchi, 2004; House et al., 2001; Barling et al., 1999; Bredahl et al., 1998). Socio-economic characteristics have also been shown to have a significant influence in people's perceptions (Li, Curtis, McCluskey, and Wahl, 2002; Hoosain et al., 2003). In the case of GM foods, socio-economic variables might be more important in a developing country context where expenditure on food constitutes a larger share of household's budget than in developed countries.

Most of these studies were conducted using consumer-based surveys; however, according to Aerni and Bernauer (2006) another way to assess the public perception about biotechnology is to analyze actors that influence public opinion through stakeholder-based surveys. This approach focuses on those actors who claim to represent some public or private interests (Laumann and Knoke, 1987). For Aerni (2005) the individual perceptions about agricultural biotechnology are ultimately influenced by the information distributed in the mass media from key stakeholders in industry, government, public interest groups and academia. Further, the selection of the sources of information is influenced by characteristics like individuals' social status, personal worldview and interests. A further advantage of this stakeholder-based approach avoids a possible bias in results due to the low awareness of GM technology by direct consumer; a very common situation in developing countries that limits the extent to perceptions can be rigorously analyzed. Also, it allows deepening in some topics because we suppose that these types of actors have an informed opinion. Studies about consumer perception typically show that responses are based on the information received from their selected sources, suggesting that the source of information might affect consumer's choices and willingness to pay (Hu, Chen, and Yoshida, 2006).

In this study, to analyze the position of stakeholders towards GM crops the stakeholder-based survey approach was applied using risk and benefits perceptions. To explain the overall attitudes (acceptance or opposition) toward GM food we used socio-demographic variables, proxies for beliefs, access to information, and relationships that stakeholders maintain with different types of actors. The underlying conceptual model is presented in the Figure 1.

3.1 The data

An inventory of 200 public and private organizations that actively participate in the GM debate in Brazil was developed based on input from key informants and a database of the CTNBio (Table 1) and key individuals in each organization were identified. A

stratified sample (by type of stakeholders) of 98 organizations was randomly selected and a structured questionnaire was applied via interviews (e-mail, telephone and in person) during July-August 2008. Individuals from government agencies (Agriculture, Agriculture Development, Environment, Health and Science and Technology), consumer and other civil society organizations, industry (local and multinational), agriculture research institutes (public and private), NGOs and members of the legislature participated in the study. It is important to note that responses reflected the personal perceptions of the respondents rather than the official positions of their organizations.

The purpose of the interview was to obtain information about the positions of the stakeholder towards GMOs in general and the possible introduction of a GM cassava enhanced with provitamin A in particular. This cultivar is being developed to combat Vitamin deficiency (VAD) as a part of a biofortification strategy, where biofortification means increasing the micronutrient content of staple food crops through plant breeding techniques (HarvestPlus, 2009). Stakeholder perceptions were assessed by asking respondents whether they agreed or disagreed with a series of statements about GMOs and GM cassava (Annex). A four-point scale ranging from 1 "totally disagree" to 4 "totally agree" was used. A fifth option "indifferent" was allowed. Respondents were also asked about their trust in institutions that provide information about GMOs, their opinions about agricultural development in Brazil, and their relationships with other actors in science and technology, agriculture and industry.

4. Results

Based on our sample, 69% of stakeholders in Brazilian biotechnology are male. Approximately 50% are agronomic engineers while 36% have backgrounds in biology or chemistry and 14% in social science. Fifty-four percent have PhDs, 18% Masters and 4% have only high school degrees. Finally, 93% and 43% said that they have no political or religious affiliations, respectively.

4.1 Stakeholder perception towards GM food

Respondents were presented with 10 statements about general perceptions of GM foods (Table 2). Both risk (negative) and benefit (positive) statements to avoid a bias. The first two statements were related to the clarity of biosafety law in Brazil and the capacity of the authorities to evaluate and monitor the GM food crops. Most of respondents agreed

that the biosafety legislation is clear and avoids the wrongful use of GM crops in the country (63%)[1].

Despite the high levels of support for existing biosafety legislation, 57% of stakeholders had negative attitudes about the nation's capacity to evaluate and monitor GM crops. They clarify that Brazil has qualified people to work in this area, but still does not have a required infrastructure to undertake the necessary activities.

Regarding perceptions about environmental damage or risk to human health, respondents are not very concerned about these topics. Only 24% and 30% respectively think that even when the biosafety guidelines are applied, GM crops are not safe for the environment or human consumption. For them, there are two main concerns. The first relates to the appropriateness of GM crops developed and tested outside of Brazil for Brazilian conditions. Second, there are no ex-post studies about long-term environmental and health risk effects of GM crops. People highlighted that it is important in each GM release event crops to conduct ex-ante evaluation studies to be sure that the GM crop is safe not only for the environment but also for human health.

According to the results, a high percentage of respondents think that GMOs technologies could generate some benefits in terms of agricultural competitiveness. Approximately 70% believe that GMOs could increase food production, potentially enhancing food security. The same percentage of stakeholders perceives that these products could reduce cost of production and increase producers' profits. More than 75% agreed that GM crops are useful to solve problems that cannot be solved by traditional breeding approach. Similar results have been found in other developing countries as Colombia, China and Argentina. Because of nutritional and competitiveness problems, GM food could be a good solution for the challenges facing developing countries (Curtis, McCluskey and Wahl, 2003)

In response to a statement about whether GM food developed by national research centers/enterprises would be more acceptable to the public than those developed by multinationals, opinions were mixed. Forty four percent consider that the type of institution that developed the GM crop is important for the consumer acceptation, while 46% think that is not important. One possible reason is that Brazil, like other developing countries, has a low level of consumer knowledge and consumer awareness on this topic (Guivant, 2006).

[1] To facilitate the reading we clubbed the two agree and two disagree responses of the fourth-point scale

The statement with eth highest level of "agreement" was about the usefulness of GM crops to solve problems unsolved by other techniques (Average score 2.98). The statement with the lowest acceptance level related to Brazil becoming a GM-free country to increase its competitiveness (Average rating =2.05). These results suggest a high level of pragmatism among biotechnology stakeholders in Brazil.

4.2 Stakeholder perception toward an introduction of a cassava with more provitamin A

The second-generation of GMOs, usually GM foods, was developed to offer direct benefits to consumers (e.g., via nutritional quality) and to the environment (Hout, 2002). Results from studies in developed countries about consumer attitudes toward GM food seem to indicate that attitudes can change: opposition to GM foods may be reduced when direct benefits are associated with them (House et al., 2001). In this study, we confirm those results. Two thirds of respondents agreed that second-generation GM crops could increase the consumer acceptance as compared to first-generation GMOs whose benefits were mainly captured by producers (Table 3). Stakeholders also perceived that nutritional benefits might be foregone if GM cassava was forbidden (60%).

In the specific case of a GM cassava with more provitamin A, the patterns of perceptions are the same. In Brazil, cassava has a high cultural, economic, nutritional and social value, and the country is also the centre of origin and genetic diversity of the crop. Most of the stakeholders, however, were not concerned about the introduction of this GM crop. They agreed with complementing current strategies to combat Vitamin A deficiency such as supplementation or strengthening the program of nutritional education and dietary diversification with the introduction of GM cassava (59%). The Biosafety Law does not prohibit the introduction of a GM crop into its centre of diversity, and this was reflected in the high percentage of responses (70%) that think that the introduction could be possible.

4.3 Characterizing stakeholder groups

We used the multiple correspondence analyses (MCA) to characterize and understand the stakeholder positions towards GM crops based on the perceptions described above. These approaches are very useful for exploring and categorizing data sets without imposing any pre-determined relationships between the variables. MCA reduces the number of variables and detects the relationships among levels of the variables (Lebart,

Morineau, and Warwick, 1984). Twenty-two descriptive variables were selected from data gathered in the questionnaire[2]. The variables with greater discriminatory power are: (a) GM crops are safe for the environment if biosafety guidelines are considered, (b) a country that is a crop origin and diversity centre (example Brazil- cassava) should not breed a GM of this crop (GM cassava), (c) to consume GM food could be risky for human health, (d) the new GM cassava with more provitamin A could have a potential ecological risk, (e) the GM cassava with more provitamin A content is against the Brazilian culture and traditional knowledge and (f) level of trust in international organizations (e.g., FAO). Although the MCA simplifies the discriminatory power of all the variables into two dimensions, some of the variables have more discriminatory power in one dimension than in the other. Such a distinction serves to describe the dimensions. For instance the variable "level of trust in international organizations" explains the dispersion along dimension 1[3].

A subsequent cluster analysis was conducted using the two dimensions that conserved around of 63% of explained variance; each dimension was weighted according to the quantity of variance explained, 43 % and 20% respectively. The first step consisted of identifying the number of clusters or groups using a dendrogram. After a hierarchical classification procedure using the Ward method, three groups of stakeholder positions were identified (Table 4 and Figure 2).

Group 1, located in the right section of Figure 2, is the largest group consisting of 66 % of respondents. The stakeholders in this group generally have a positive attitude toward GM food. Approximately 85% agree that there are potential benefits of GM food, and 91% are not worried about the environmental and health risks. Eighty three percent of this group agrees with the introduction of a GM cassava with more provitamin A in Brazil, which is very similar to the percentage of acceptance of GM food in general in this group. Stakeholders in this group are less concerned about risks of introducing of a GM cassava in its origin centre (Brazil), and they do not believe that current efforts to combat VAD are sufficient.

Group 2, in the middle section of Figure 2, consist of 19 respondents with a moderate, pragmatic position towards GM crops. Most of them agree with the use of

[2] *Initially we began the study with forty variables. However, according with MCA results only twenty-two variables had discriminatory power.*

[3] *The discriminatory power is related with the heterogeneity of the answers, this means that variables excluded are because the answers are very similar (homogeneous). Eigenvalues are the new variables obtained with the MCA, they are useful to interpret the dimension results.*

GM crops in general, however they do not agree with the introduction of a GM cassava with more provitamin A. Only 37% of the members of this group support the idea. The main reason is because Brazil has other tools available to combat VAD; therefore it is not necessary to use genetic modification. Having said that, the members of this group think that in other places such as Africa with fewer alternatives for fighting VAD, GM cassava could be useful. This group has two individuals (at the lower part of the graph) with behavior slightly different. They are characterized by not taking a position toward the statements. Most of their answers are 'indifferent'.

Group 3 (in the upper-left in Figure 2) is the smallest with 14 respondents. Their perceptions of GM crops are mostly negative. They find no potential benefits either for GM crops in general or for the specific GM cassava. This group has links to international and national NGOs. They have little trust in GM-related information coming from universities, or international and national research centers , and none at all when the information is from mass media, government agencies, local and multinational industries.

The MCA results also reveal the relative differences and similarities among the groups in terms of the characteristics of their members (Figure 3). Points located farthest from the center indicate that the characteristic is unique to the type of group. This does not imply that the groups are only defined by these characteristics but rather that the attributes are not present in the other groups. In contrast, points located near to one of the 0-0 axes signify that the characteristic pertains to more than one group. The link between the cluster analysis and the MCA comes in superimposing the centers of the graphics.

The main attributes of Group 1 are the high representation of stakeholders related to industry and government agencies, most of whom are located in the south of Brazil where agriculture is more industrialized and most likely to benefit from new technologies. All the stakeholders in this group believe that science is extremely necessary to resolve agricultural problems.

Group 2 is associated with the academic sector. This group has the highest level of education, and most of them studied a career associated with biology and chemistry, compared to Group 1 (agriculture science) or Group 3 (agriculture and social sciences). Group 3 doesn't have representation in industry or government agencies; most of the stakeholders are NGOs, with a few from universities and research centers. The

organizations of this group are mainly located in the North of Brazil, and their level of education is the lowest among the three groups.

It has been hypothesized that the relations of stakeholders determine in some degree their perceptions (Paarlberg, 2003). In the last part of the survey respondents were asked if they have relationships with specific types of organizations. If they said yes, the next questions were the type of relation (commercial, financial or cooperation) and strength of relation (less strong, strong and very strong). Most of the stakeholders have many relationships; and all groups are related in some way with government agencies, mass media and research centers. Groups 1 and 2 both mainly have relationships with local and multinational industries and Group 3 with local and international NGOs. These results are consistent with the studies about public opinions of GM crops in developed countries (Curtis et al., 2003). The debate between NGOs and industry is being moved to developing countries. In the case of Brazil this situation is reflected at high political levels**,** but not yet at consumer levels as some studies showed (Guivant, 2006).

5. Factors that Influence the Stakeholder Positions

To assess the factors (variables) that influence perception of the stakeholders we estimated a logit model to explain responses to the two statements with the greatest discriminatory power, which also characterized very well the topics of this study. The first one was: To become a 'GM-free' country is NOT a good strategy to increase the competitiveness of Brazil in the global market; the second was: a country that is a crop origin and diversity centre (example Brazil-cassava) could use GM versions of this crop (GM cassava). We used the results of the four-point scale and transformed them into dummy variables depending if stakeholders agreed or not with the statement. Around of 68% of stakeholders agreed with GM-free country strategy could not improve the competitiveness of Brazil in the world market, while 40% prefer to avoid the introduction of GM crops when the country is the diversity and origin centre.

Socio-demographic characteristics as age (years), education and religion were considered as explanatory variables. As a proxy for belief, we used respondents understanding of the sustainable agriculture, specifically if this production system implies low or zero levels of chemical fertilizers and pesticides. To avoid correlation problems between source information and stakeholder relations, we did not include the former. Stakeholder relationships were included as dummy variables that show the

stakeholder relations with main institutions or sectors related to this topic. We expected the same coefficient sign for both equations since both statements reflect a positive attitude towards GMOs.

Many of the socio-demographics are significant and their coefficients have the expected signs (Table 5). In both cases, unsurprisingly having a PhD is a positively and statistically associated with agreeing with the statements (Juma et al., 2007). In our case, older respondents have a more positive attitude towards GM biofortified cassava, which is consistent with findings of Kim and Boyd (2004) and Han and Harrison (2006). Stakeholders who practice a religion are not more likely to have problems with the introduction of a GM version in its centre of diversity than non-religious people. In general, the Catholic Church does not have a position against GM technology, if it targets the problems of the poor (Nicholson, 2004).

Having relationships with NGOs is negatively associated with agreeing with the statement regarding the GM-free strategy for agricultural development. The negative relationship is logical taking into account that most of the NGO's are the main opponents of these technologies, at both the international and national levels. They have initiated many campaigns to avoid the introduction of GM crops in Brazil, and they were successful up until the Biosafety Law. Currently they have taken this 'battle' to the consumer level.

As expected, stakeholders with ties to industry support GM crops. This sector in Brazil, as in other countries, has been the key supporter of GMOs development (Pray, Paarlberg, and Unnevehr, 2007). Relationships with the research sector are not statically significant. Finally, respondents who consider that a sustainable agriculture implies a low or null level of chemical fertilizers and pesticides are strongly opposed in general to GM foods, though not to GM cassava in particular. Some studies have shown that the more important the role of values the less important new information becomes in order to shift people's behavior (Costa-Font, Gil and Traill, 2008), however according to our results this may not be the case in Brazil.

6. Conclusions

In general the perceptions of stakeholders about potential benefits of GM food are positive in Brazil. However, as has occurred in other developing countries, external forces are trying to create a polarization toward this technology. This situation was reflected by the prohibition of planting GM soy during 10 years in Brazil. In 2005, new

legislation allowed such crops to be commercially available. Most of the stakeholders think that the law provides adequate orientations for evaluating and monitoring GM crops in Brazil, but efforts to improve the capacity to carry out such activities are needed in order to ensure the biosafety in the country.

According to our results, there are three groups main groups of stakeholders in Brazilian biotechnology, whose positions towards GMOs can be characterized positive, negative and pragmatic. Local and multinational industries and part of the government form the biggest group. They have highly positive attitudes towards GM crops for food in general and would support the introduction of a GM cassava enhanced with provitamin A. International and national NGOs form the smallest group, they are more skeptical about the benefits of these technologies. Finally, remaining group, consisting mainly of the research sector, has a moderate opinion, positive or negative depending of the particular GM crop. This group is highly trusted by public opinion; which implies that it could play an important role in shaping the broader public perception toward GM food in Brazil.

These results in Brazil confirm the hypothesis that second-generation GM crops are likely to meet with greater public acceptance than first generation GMOs. However, this acceptance is not unconditional; rather stakeholders evaluate the tradeoffs between the tangible benefits received by consumers and any potential risks. In the specific case of a GM cassava biofortified with provitamin A, two traits are important: the micronutrient increase and the fact that Brazil is a centre of origin and diversity for cassava. According to the results of this study, while most stakeholders are generally supportive of GMOs, some question the necessity of a GM strategy for VAD. If these concerns are not addressed, the introduction of cassava with provitamin A in Brazil could face opposition not only from NGOs but also from the more moderate sectors such as academic and research whose influence over public opinion may be significant.

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Annex

Perceptions about GM crops for food

2.1 The biosafety regulation in Brazil is clear and avoids the wrong use of GM crops in the country.

2.2 Brazilian institutions do not have enough capacity to evaluate and monitor the impact of the GM crops.

2.2 The production of GM crops implies serious ethical problems

2.3 GM crops are safe for the environment if biosafety guidelines are considered.

2.4 To consume GM food could be risky for the human health

2.5 GM crops are useful to solve problems, which could not be solved by the traditional breeding approach.

2.6 GM food crops could help to ensure the food supply in Brazil.

2.7 To become a 'GM-free country' is a good strategy to increase the competitiveness of Brazil in the global markets.

2.8 GM crops could reduce some cost of production so that their revenues could increase.

2.9 GM crops developed by national research centers/enterprises have more public acceptance that those developed by multinationals.

Perceptions about an introduction of a GM modified cassava with more Provitamin A

3.1 The second-generation of GM crops will find more public acceptance in Brazil because of the nutritional qualities that consumers may find appealing.

3.2 A country that is a crop diversity and origin centre (example Brazil- cassava) should not use GM versions of this crop (GM cassava).

3.3 Because of the failure to approve GM food crops consumers in Brazil could lose many nutritional benefits.

3.4 It is better to continue using the current strategies to combat vitamin A deficiency (VAD) than to introduce a complementary tool as a new genetically modified cassava with more provitamin A.

3.5 A new GM cassava with more provitamin A could have a potential ecological risk.

3.6 The GM cassava with more provitamin A is against the Brazilian culture and traditional knowledge.

3.7 It is possible the introduction of a new cassava with more provitamin A in Brazil

Table 1. **Inventory and sample**

Organizations	**N**	**Sample**
1. Non-Governmental Organizations (environmental, industrial, consumer organizations)	49	20
2. Public Authorities: Government & Legislators **- Ministries: Agriculture, Science and Technology, Health, Environmental and Agricultural Development** **- State institutes of agriculture** **- Financial public institutes** **- Legislators**	32	18
3. Local industries and Multinationals	59	24
4. Universities	36	19
5. National research centers (public and private research centers)	24	17
Total	200	98

Table 2. **Stakeholder perceptions about GM crops**

.

Perceptions (%)	**Totally disagree**	**Disagree**	**Agree**	**Totally agree**	**Indifferent**	**Mean value [a]**
The biosafety regulation is clear and avoids the wrong use of GM crops	12.2%	22.5%	53.1%	10.2%	2.0%	2.63
Brazilian institution do not have capacity of monitoring GM crops	31.6%	8.2%	18.4%	38.8%	3.1%	2.31
Production of GM crops implies ethical problems	16.3%	40.8%	28.6%	10.2%	4.1%	2.34
GM crops are safe for the environment	5.1%	18.4%	48.0%	22.5%	6.1%	2.93
To consume GM food could be risky for the human health	14.3%	50.0%	23.5%	6.1%	6.1%	2.38
GM crops are useful to solve problems, which could not be solved by other approach.	6.1%	12.2%	55.1%	22.5%	4.1%	2.98
GM food crops could help to ensure the food supply in Brazil.	11.2%	18.4%	50.0%	19.4%	1.0%	2.78
To become a "GM-free " is a good strategy to increase the competitiveness of Brazil	25.51%	42.86%	24.5%	3.06%	4.08%	2.05
GM crops could reduce some cost of production so that their revenues could increase.	3.1%	23.5%	61.2%	10.2%	2.0%	2.80
GM developed by national research centers have more acceptance that those developed by multinationals.	40.8%	6.1%	35.7%	8.2%	8.2%	2.51

Note. The statements are valuating between 1 and 4, where 1 means 'totally disagree' and 4 means 'totally agree'.
[a]The 'indifferent' category was excluded.

Table 3. **Stakeholder perceptions about an introduction of GM cassava with provitamin A**

Perceptions (%)	Totally disagree	Disagree	Agree	Totally agree	Indifferent	Mean value[a]
The second-generation of GM crops will find more public acceptance because of the nutritional qualities	3.1%	26.5%	9.2%	58.2%	3.1%	3.26
A country that is a crop diversity centre (example Brazil- cassava) should not use GM versions of this crop	12.2%	46.9%	11.2%	21.4%	8.2%	2.46
Because of the failure to approve GM food crops consumers could lose many nutritional benefits.	12.2%	22.4%	9.2%	50.0%	6.1%	3.03
It is better to continue using the current strategies to combat VAD than to introduce a complementary tool as a GM cassava	12.2%	45.9%	27.6%	12.2%	2.0%	2.75
A GM cassava with more Provitamin A could have a potential ecological risk	12.2%	44.9%	7.1%	22.4%	13.3%	2.46
The GM cassava with more provitamin A is against the Brazilian culture and traditional knowledge.	20.4%	44.9%	7.1%	21.4%	6.1%	2.32
It is possible the introduction of a new cassava with more provitamin A in Brazil	5.1%	19.4%	10.2%	59.2%	6.1%	3.32

Note: The statements are valuating between 1 and 4, where 1 means 'totally disagree' and 4 means 'totally agree'.
[a]The 'indifferent' category was excluded.

Table 4. **Characterization of group perceptions (clusters)**

Perceptions: % agreeing	**Clusters**		
	Group 1 (n =65)	**Group 2** (n = 19)	**Group 3** (n = 14)
The biosafety regulation is clear and avoids the wrong use of GMO	84.62	36.84	0.00
Brazilian institution do not have capacity of monitoring GM crops	29.23	47.37	78.57
Production of GM crops implies ethical problems	15.38	78.95	92.86
GM crops are safe for the environment	90.77	52.63	0.00
To consume GM food could be risky for the human health	9.23	52.63	92.86
GM crops are useful to solve problems, which could not be solved by other approach.	92.31	63.16	28.57
GM food crops could help to ensure the food supply in Brazil.	84.62	57.89	14.29
To become a 'GM-free' is a good strategy to increase the competitiveness of Brazil	10.77	31.58	100
GM crops could reduce some cost of production so that their revenues could increase.	90.77	47.37	14.29
GM developed by national research centers have more acceptance that those developed by multinationals.	45.31	52.63	28.57
The "second generation" of GM crops will find more public acceptance because of the nutritional qualities	86.15	42.11	14.29
A country that is a crop diversity centre (example Brazil-cassava) should not use GM versions of this crop	12.31	57.89	92.86
Because of the failure to approve GM food crops consumers could lose many nutritional benefits.	75.38	26.32	28.57
It is better to continue using the current strategies to combat VAD than to introduce a complementary tool as a GM cassava	21.54	73.68	78.57
A GM cassava could have a potential ecological risk	10.77	42.11	100
The GM cassava with more provitamin A is against the Brazilian culture and traditional knowledge.	10.77	42.11	92.86
It is possible the introduction of a GM cassava with more provitamin A in Brazil	83.08	36.84	50.00
Trust in international NGOs	10.45	28.57	78.57
Trust in local NGOs	4.48	28.57	57.14
Trust in universities	80.60	71.43	28.57
Trust in mass media	7.58	7.14	0.00
Trust in government	34.33	21.43	0.00
Trust in local industries	28.36	0.00	0.00
Trust in multinational industries	38.81	7.14	0.00
Trust in international organizations	95.52	71.43	28.57
Trust in national research centers	89.55	71.43	14.29
Trust in international research centers	94.03	57.14	21.43

Table 5. **Logit models**

Variables	GM-Free is NOT a good strategy of competitiveness [a]		GM cassava could be used in its diversity centre [b]	
	Coef.	Std. Err.	Coef.	Std. Err.
Age of respondent (years)	0.06*	.04	.02	.02
PhD, dummy (yes=1)	2.09***	.77	.97*	.55
Religion, dummy (yes=1)	-.67	.68	.87*	.52
Sustainable agriculture, dummy (yes=1)	-2.27***	.75	-.70	.60
Relations with NGOs, dummy (yes=1)	-1.33*	.78	-.73	.57
Relations with Industry sector, dummy (yes=1)	1.51*	.81	1.51**	.63
Relations with Research sector, dummy (yes=1)	.88	1.07	-.69	.79
Relations with Government sector, dummy (yes=1)	.-1.48	1.15	-1.99**	.92
Intercept	-.87	1.75	-.58	1.33
Log likelihood	-32.91		-38.49	
Chi-squared	50.94***		27.08***	

[a] N:95

[b] N:97; *,**,*** Statistically significant at the 0.10, 0.05 and 0,01 level, respectively.

Figure 1**. Benefits/risk perception on GM food**

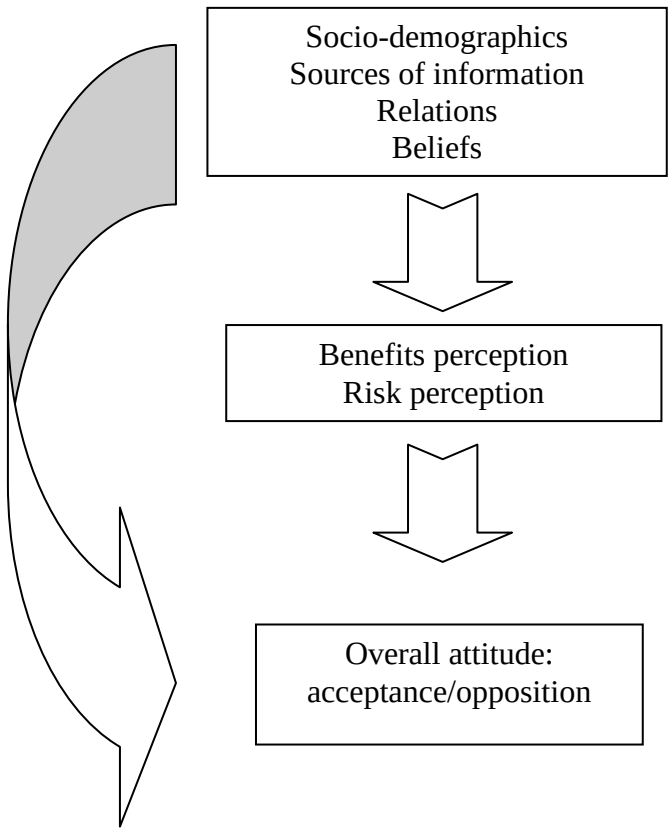


Figure 2. **Cluster Analysis (N=98)**

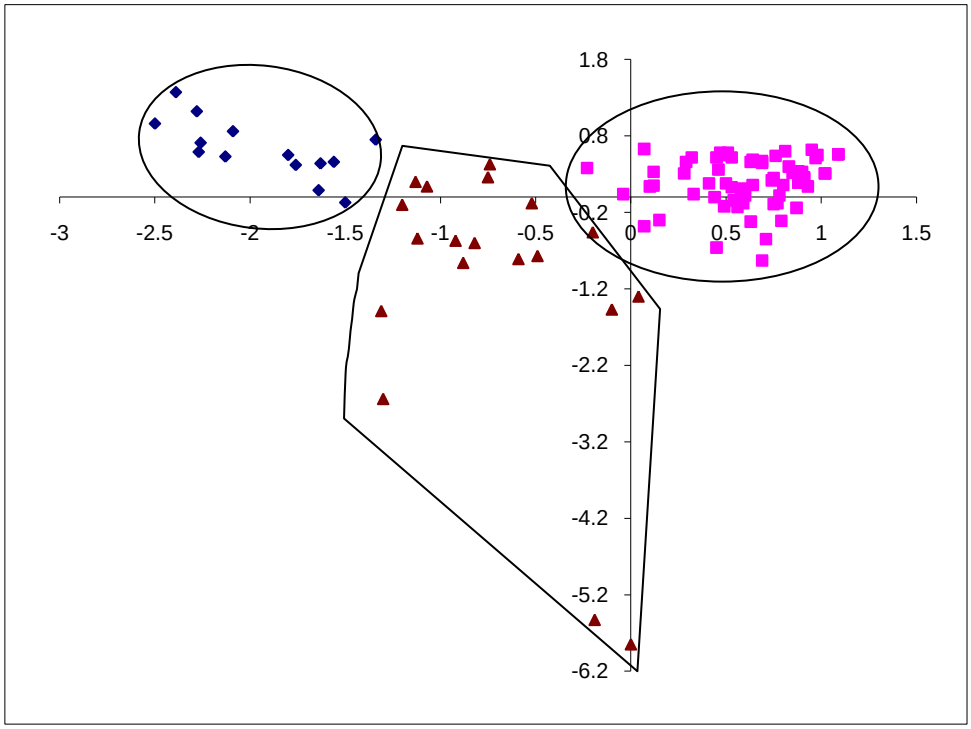
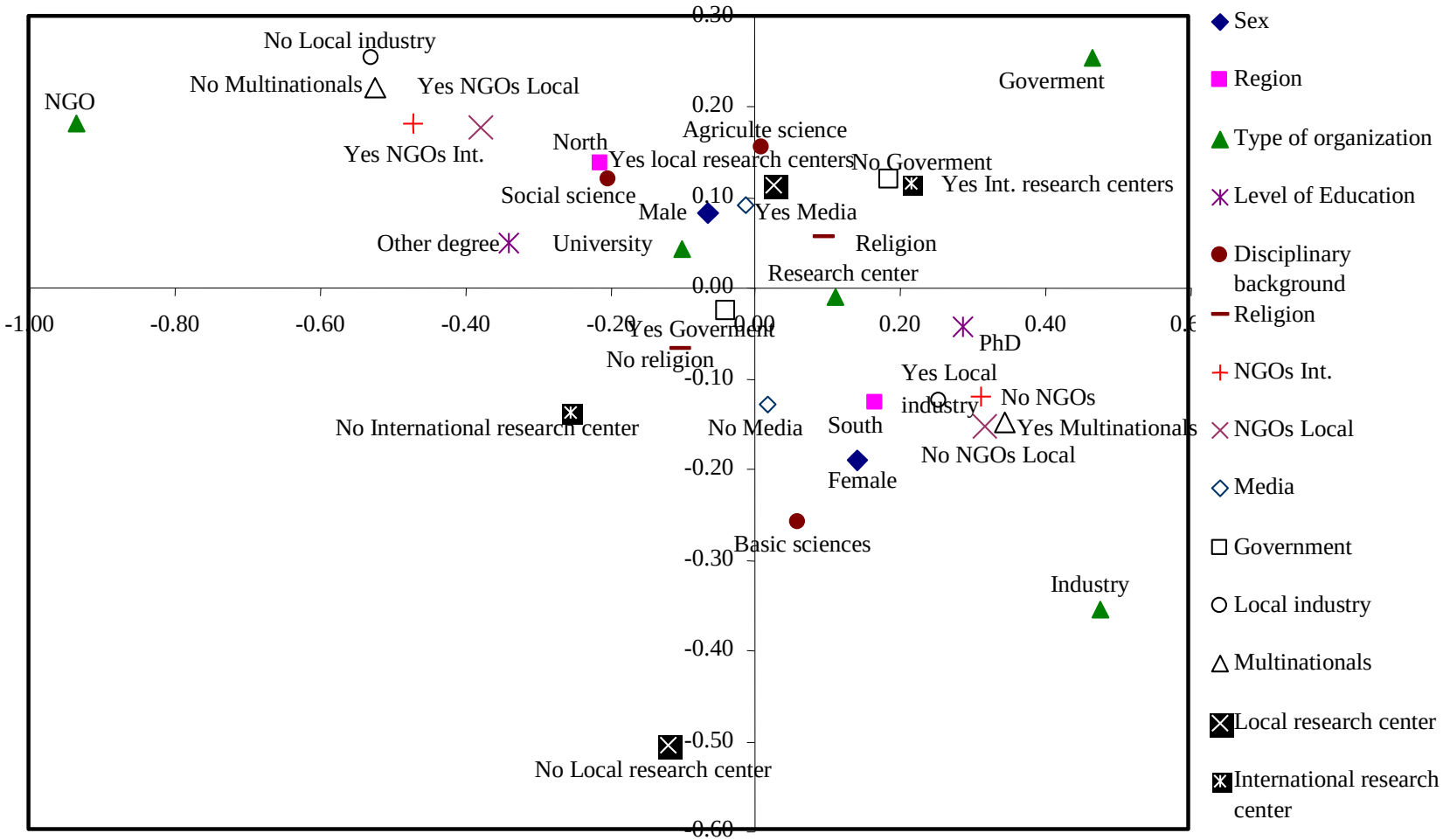


Figure 3. **MCA Analyses**



CHAPTER 5

CONCLUSIONS

Second-generation GM crops were developed to offer consumers benefits through enhanced quality attributes or nutritional characteristics. Studies carried out in developed countries suggest that these new characteristics could increase the public acceptance of GM crops. However, only a few pertinent studies have been conducted on this topic. Therefore additional information is required to be able to determine the different attitudes of consumers toward these products, especially in developing countries. This study seeks to provide valuable insight in this area and its results will serve as input to fill current knowledge gaps related with these topics.

Biofortification is a novel process to combat micronutrient malnutrition by breeding staple crops for higher micronutrient contents. A complementary strategy to existing micronutrient interventions, biofortification offers several advantages: first, it's sustainable because it improves the nutritional content of staple foods that are already consumed by the poor, and second, it's low cost because after the initial investment of developing a biofortified crop, additional varieties can be generated at a relatively low cost for use in different regions and for years to come. Scientists of the CGIAR HarvestPlus Challenge Program are working on increasing the micronutrient contents of different staple crops, mostly using traditional plant breeding techniques. However, some nutrients cannot be bred into food staples using conventional methods, but require the use of biotechnology to obtain nutrient contents that are sufficiently high to make a difference from the nutritional viewpoint. This is the case of provitamin A in cassava.

This study examined the consumer acceptance in Brazil of GM cassava with enhanced provitamin A content, using preference data. The aim was to understand how consumer's value different attributes of the final product and the trade-offs involved, including whether or not biotechnology was used for crop biofortification. In addition, existing uncertainties about the positions of stakeholders regarding GM foods in Brazil were analyzed. The position of stakeholders can significantly influence the efficiency of regulatory approaches and, as a result, the effects of second-generation GM crops on consumer wellbeing. Although similar studies have been carried out in developed countries, the evidence suggests that the insights obtained from these studies cannot be simply transferred to developing countries. The results of the present study therefore

add novelty to existing literature and contribute to the broader policy debate on GM crops in a development context.

Micronutrients comprise vitamins and minerals needed by the human body for its metabolic activities, the functioning of its immune system, and cell growth. Vitamin A plays an important role in body functions such as sight, immune defense, maintenance of body tissues, cell development, and reproduction. Vitamin A deficiency (VAD) is widespread in poor countries and regions, leading to serious nutrition and health problems, especially among children and women. VAD increases the prevalence and severity (morbidity and mortality) of infectious diseases and may generate severe eye problems, including permanent blindness. As a result, VAD implies high costs for national health systems and for the economy as a whole.

The empirical analysis of this study focused on NE Brazil, where poverty rates are relatively high and VAD widespread. Using secondary food consumption data, the average vitamin A intake in NE Brazil was found to be only 334 µg/day, which is much lower than the recommended dietary allowance of 750 µg/day. The situation is especially serious for vulnerable groups, including children less than five years of age and pregnant and lactating women. A child has to consume at least 500 µg/day of vitamin A for normal development, but in NE Brazil the average intake of children is only 60% this requirement. Similarly, women need, on average, 700 µg/day of vitamin A, but mean consumption levels are only about 50% this level. The literature suggests that there is a negative correlation between the level of income and micronutrient malnutrition, a fact which is confirmed by this study in the case of VAD in NE Brazil.

Cassava is an important staple food crop for many poor consumers worldwide; it forms part of the daily diet and is an important source of calories for low-income populations. In Brazil, cassava has other relevant aspects beside its nutritional importance. The country is the center of diversity of this crop and many dishes of traditional Brazilian cuisine are based on cassava and/or its byproducts. As a result, any cassava biofortification program has to take into account broader aspects when comprehensively analyzing potential consequences.

The main empirical parts of this dissertation were built on comprehensive surveys of consumers and stakeholders, both carried out by the first author. The former survey is representative of households in medium-sized municipalities of NE Brazil and, accordingly, of the region's fresh cassava market consumers. It is important to highlight

that obtained results reflect the consumer perceptions during the time that this study was developed, and according to the information on the topic that was provided to them. Regarding to the second survey, the total population of stakeholders in Brazil related to GM crops is difficult to determine. For this reason, results are not fully representative. However, they have a societal significance, since the data analysis illustrates the events and dynamics of stakeholders in Brazil related to this subject.

For the new technology to be widely adopted and used, it is necessary to understand consumer preferences regarding cassava attributes. Such information can help researchers select suitable varieties for further research and genetic modification. Moreover, adding provitamin A has implications for the flesh color, which turns to dark yellow. It is therefore important to predict consumer reactions to this color change. The results of statistical analyses show that the most important attributes when consumers purchase or eat cassava are ease of peeling, time of cooking, and texture. Color also plays an important role, with yellow being less preferred than white. Unsurprisingly, preferences vary somewhat by region. In the coastal region, existing yellow varieties are not very well known and less preferred, whereas in the semiarid hinterland both white and yellow cassava varieties are consumed. Sometimes yellow varieties even fetch higher prices.

Impact assessment studies conducted by HarvestPlus indicate potential health gains through the introduction of provitamin A cassava. However, these studies did not consider that new varieties might be genetically modified. To better understand acceptance levels in Brazil, consumer attitudes were analyzed. The consumer survey data revealed that half of the respondents have some knowledge about vitamin A, but that the awareness of biotechnology is very low. This issue was addressed by providing objective information in the form of a script. The survey indicated that the overall attitude towards GM crops in Brazil is relatively positive. Three-quarters of the respondents stated that, in general terms, they would support the introduction of GM provitamin A cassava. Using contingent valuation techniques, consumers' willingness to pay (WTP) averaged a price premium of 64% over the current price of conventional cassava, which implies a high level of acceptance. This also suggests that consumers would appreciate the associated nutritional benefits so that social welfare levels would increase because of the introduction of this technology. While the mean WTP might appear relatively high, it is not unrealistic, as cassava is relatively cheap anyway,

accounting for less than 2% of the mean total household expenditures. Nonetheless, the idea is not to sell biofortified cassava at a premium price, because this could certainly lead to accessibility problems among the poor. The technology is being developed by the public sector with the aim to reduce malnutrition among the poor, so a low price should be sought to enable easy access. Therefore, the WTP analysis should not be misinterpreted as a strategy to determine feasible price markups, but rather as a tool to better understand consumer preferences. Household income levels do not have a significant effect on the WTP. However, other socioeconomic variables such as the respondent's sex or whether or not a household has children do affect the WTP. Females and households with small children have a higher WTP, which is plausible, as they might especially benefit from provitamin A biofortification. These results bode well for the future introduction of the technology in Brazil.

The results also confirm previous studies that have shown that GM food acceptance is often higher in developing than in developed countries. A possible explanation is that consumers in developing countries are generally poorer and sometimes food-insecure, so that they are more open to test products that improve their quality of life without significantly affecting their budget.

An additional choice modeling exercise has shown the trade-offs between different cassava characteristics: for the vitamin A attribute alone, the average consumer WTP is a large premium of 160%. However, a discount is required for the cassava color 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, which have to decide between conventional and GM breeding techniques. When there is a choice, 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 no arguments against GM techniques per se, especially 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.

Overall, the consumer results bode well for the introduction of GM provitamin A cassava in Brazil. They also confirm earlier findings from developed countries, showing that second-generation GM crops with direct consumer benefits are valued

more positively than first-generation technologies that only involve agronomic traits. However, some caution is warranted with respect to the interpretation of the results, as much of the analysis builds on stated preference data, which might be associated with a certain degree of hypothetical bias.

Another factor that could potentially have an impact on the introduction of second-generation GM crops is the attitude of different stakeholders and the wider public. Developing countries have become a battleground between proponents and opponents of GMOs, between the governments of developed countries and non-government organizations (NGOs) that try to influence the position of developing countries regarding biotechnology. Brazil is not the exception. Since 1995, when the country attempted to formulate its national biosafety legislation, the policies on GM crops have been polarized. However, in general, stakeholder perceptions of GM foods are relatively positive in Brazil, as indicated by the results of the stakeholder survey.

Three groups of stakeholders can be distinguished—those in favor of GM crops, those against, and those who have a more or less neutral position. Representatives of local and multinational industries and diverse government authorities belong to the first group; international and national NGOs form the second group, while scientists are mostly found in the third group. Sources of information and institutional/personal relationships influence the positions of individual stakeholders, as do various socio-demographic characteristics, such as the level of education and age. Another important finding of the survey was the high level of trust that Brazilian consumers and other stakeholders generally have in the country's research and academic sectors. Therefore, taking into account the relevance of information and the role played by the research sector, an effective distribution system of GM crop information via government agencies and/or the public media is needed to complement the knowledge of consumers so that they can make their own informed decisions.

In the specific case of GM provitamin A cassava in Brazil, another aspect should be considered: the country is the center of genetic diversity for cassava. This might lead to stricter biosafety guidelines and potentially to steeper opposition by environmental groups. This should also be taken into account in a broader cost-benefit analysis, which is beyond the scope of this dissertation.

ANNEX

1. HOUSEHOLD QUESTIONNAIRE

Schedule Number: _____ Date of interview: _____
Name of the interviewee:_____

CONSUMER ATTITUDES TOWARD GENETICALLY MODIFIED CASSAVA

1. Full name of respondent: _____
2. Sex : **F** **M**
3. Municipality: _____
4. Address:_____
5. Point of reference:_____
6. Telephone:_____

I. Food acquisition patterns

7. Normally, who decides what food products are purchased? (*Tick only one*)

1. Woman (wife or mother)	
2. Man (husband or father)	
3. Both	
4. Other(s) *(specify)* _____	

8. Normally, where do you **mainly** get fresh cassava and farinha (processed cassava) from? (*Tick one or more*)

	Fresh Cassava	**Farinha**
1. Own production (including kitchen garden)		
2. Farmers directly		
3. Small shops		
4. Local markets		
5. Supermarkets		
6. Others *(specify)*_____		
7. Never use		

9. How many times do you (and your family) eat cassava per week?
10. How many kilograms of cassava do you (and your family) eat per week?:_____
11. How many do you spent in cassava per week?:_____
12. How many times do you (and your family) eat farinha per week?
13. How many kilograms of farinha do you (and your family) eat per week?:_____
14. How many do you spent in farinha per week?:_____
15. Do you consume the same amount of cassava year-round?
    Yes☐ (**IF THE ANSWER IS YES**, **go to q-no. 19)** No☐ Don't know ☐

16. Do you eat cassava year-round? Yes □ No □

17. **If the answer to the previous question was NO**, then please indicate the month or months that you eat cassava.

_____

18. **If you do not eat cassava**, which food products do you consume to replace it?

_____

II. Preferred consumption characteristics

19. Which are the most important attributes considered while purchasing fresh cassava? Compare these attributes among themselves rank them in the order of your preference (*Give the three most important).*

Attributes	Rank	Preferences
1. Time of cooking		Yes □ No □
2. Market price		
3. Color		Which?_____
4. Texture		Mushy ___ Mealy ___
5. Taste		Sweet __ Neutral __
6. Fibers		Much fibers __ Low fibers __
7. Ease peeling		Yes ___ Indifferent___
8. Others *(specify*):_____		

20. Do you consume yellow cassava in the household? Yes ( ) No ( )

21. Why? _____

22. Which are the most important attributes considered while purchasing fresh cassava? Compare these attributes among themselves rank them in the order of your preference (*Give the three most important).*

□ □

Attributes	*Rank*
1. Market price	
2. Color	
3. Freshness	
4. Taste	
5. Others *(specify*):_____	

23. Do you consume yellow farinha in the household? Yes ( ) No ( )

24. Why? _____

25. Are there any problems if the people eat fresh cassava during: (*Tick one option in every row)*

1. Pregnancy?	Yes☐ No☐
2. Nursing?	Yes☐ No☐
3. Childhood (<1 year old)?	Yes☐ No☐
4. Menstruation?	Yes☐ No☐
5. Others:_____	Yes☐ No☐

Hedonic price

26. Please state the varieties of cassava that you consumed during this last months:

		Variety I Name: _____	Variety II Name: _____	Variety III Name: _____
1. Price (R$)/kg.				
2. Characteristics	1. Color (1, white; 2, yellow; 3, other)			
	2. Size (1, fine (18 –40 mm); 2, medium (41-55 mm); 3, thick (>55))			
	3. Taste (1, sweet; 2, neutral)			
	4. Texture (1, mushy; 2, mealy)			
	5. Fibers (1, much; 2, low)			
	6. Time of cooking (minutes)			
	7. Ease of peeling (1, ease; 2, indifferent)			
3. Quantity consumed (week/kg)				

III. **Awareness**

27. Do you know something about vitamin A? Yes☐ No ☐

IF THE ANSWER IS <u>NO</u>, READ THE DESCRIPTION ALOUD ABOUT VITAMIN A.

28. Name some consequences of vitamin A deficiency: (*Tick one or more*)
(DO NOT READ OUT OPTIONS TO THE RESPONDENT)

1. Eyes problems	
2. Night blindness	
3. Blindness	
4. Measles	
5. Others:_____	
6. Don't know	

29. Name some products that are good for protecting eyesight? (*Tick one or more*)
(DO NOT READ OUT OPTIONS TO THE RESPONDENT)

1. Carrot	
2. Pumpkin	
3. Green vegetables	
4. Liver	
5. Mango	
6. Others (*specify)*:_____	
7. Don't know	

30. Are there children or adults in the household who have problems with eyesight at night? Yes ☐ No ☐

31. Are there children or adults in the community who have problems with eyesight at night? Yes ☐ No ☐

32. Currently there is an institution that works to increase the amount of vitamin A in some crops. How are you willing to consume a cassava with more vitamin A?

1. Very willing	
2. Somewhat	
3. Not very	
4. Would avoid	

33. Which is the price that you currently buy cassava? R._____

34. Suppose a cassava that has more vitamin A, is entering to the Brazilian markets.

1. If the cassava with vitamin A were more expensive than traditional by (*currently price**____) ____/kg, and the new price were *(currently price+ $ incremented)*_____ /kg. Would you prefer to purchase it?

YE

2. Suppose the price of cassava with Vitamin A is more than the traditional cassava (*currently price**____) and the new price were _____ /kg. Would you prefer to purchase it? Yes ☐ No ☐

NO

3. Suppose the price of cassava with Vitamin A is more than the traditional cassava and the new price were *(currently price*____)*_____ /kg. Would you prefer to purchase it? Yes☐ No☐

35. Which is the maximum amount that you are willing to pay for the cassava with more vitamin A? 1. R$ ____ 2. Nothing ___.

36. Why? (*Tick one or more*) **(DO NOT READ OUT OPTIONS TO THE RESPONDENT)**

1. I don't have more money	
2. I don't care with this problem	
3. I don't have vitamin A deficiency	
4. It is a nutritional food	
5. Good for health	
6. Others *(specify)*_____	

37. Do you watch / listen / read agricultural and/or health-related articles or programs in: (*Please tick one in each row*)

	Frequently	**Occasionally**	**Never**
1. Television			
2. Radio			
3. Newspaper			
4. Magazines			
5. Health center			
5. Others *(specify)*			

38. Are you familiar with the following public health programs in your community? Do you participate in them?

	Know		Participate	
	Yes	No	Yes	No
1. Programs targeted at pregnant women				
2. Programs targeted infants (<1 year) (supplementation, vaccines)				
3. Programs targeted at children				
4. Hygiene education				
5. Health education on proper nutrition				
6. Others (*specify)*:_____				

39. There are many government authorities to regulate the public-health comforts – for example, food inspectors monitoring the quality of packed foods (bottled drinking water etc). In your opinion, how effective are these government regulatory agencies in ensuring the safety of the food products? (*Tick only one*)

1. Very effective	
2. Effective	
3. Ineffective	
4. Highly ineffective	
5. Don't know	

IV. Attitudes towards technology and GM foods

40. Take the case of fresh cassava. Can you differentiate its local varieties from the hybrid and/or modern varieties? Yes ☐ No ☐

41. If YES (**otherwise go to q-no. 44**), suppose you are supplied with two types of fresh cassava in the market. One is local variety and second one is hybrid/modern variety Both are available at R$____. Which one would you buy? (*Tick only one*)

Local	Hybrid / Modern	Indifferent

42. **If the answer is local (otherwise go to q-no. 44):** The reason(s) behind your selection of local variety is/are: (*Tick one or more*)
(DO NOT READ OUT OPTIONS TO THE RESPONDENT):

1. Superior taste	
2. More nutritious	
3. Cooking quality	
4. Texture	
5. Others *(specify)*:_____	

43. Suppose the price of local cassava variety is above the modern varieties by

R$. _____ /kg *(market price *____).* Would you buy the local one?

Yes ☐ No ☐

44. How are you willing to consume food products (e.g. Fruits, vegetables or grains) with new characteristics (flavor, colour, etc.)?

1. Very willing	
2. Somewhat	
3. Not very	
4. Would avoid	

45. Have you ever heard the term **biotechnology**? Yes ☐ No ☐

46. Have you ever heard about **genetically modified** or **transgenic crops**?

Yes ☐ No ☐

IF NO, go to the questions 54

47. Have you ever heard about one or more of the following crops? (*Please tick one in each row*.)

	Yes	No
1. Insect resistant Bt cotton		
2. Golden rice		
3. Herbicide tolerant soybean		
4. Insect resistant Bt maize		

48. How well were you informed about GM foods? (*Please tick one.)*

1. Very well	
2. Somewhat	
3. Just heard	
4. Not inform	

49. Are GM foods available in the market place? (*Tick only one.*)

Yes	No	No idea

50. Which are your mainly source(s) of information about genetically modified crops is/are: *(Please tick one or more)* **(DO NOT READ OUT OPTIONS TO THE RESPONDENT)**:

1. TV	
2. Radio	
3. News paper	
4. Weekly	
5. Newsletter	
6. Internet	
7. School/college	
8. Religious organizations	
9. Friends/neighbors	
10. Don't remember	
11. Others (please specify):_____	

51. How safe or risky are GM foods to human health (*Tick only one*):

1. Very safe	
2. Safe	
3. Risky	
4. Very risky	
5. Neither	
6. Don't know	

52. Are you willing to consume food product with GM ingredients?

1. Very willing	
2. Somewhat	
3. Not very	
4. Would avoid	

53. There are differences in opinion regarding the usefulness of GM crops in Brazilian Agriculture. Some organizations favor, while some oppose it. In this regard, please **indicate three** organizations from the list of 7 that you trust most regarding the reliability of the information supplied. *(Please rank.)*

1. Non-governmental organizations (NGOs)	
2. Universities	
3. Public media	
4. Public Authorities (Government)	
5. Industry (for example seed firms)	
6. Political parties	
7. Religious organizations	

Explanation given to the respondent about GM crops:

READ THE DESCRIPTION ALOUD ONLY TO THOSE WHO HAVE *NOT HEARD* ABOUT GENETICALLY MODIFIED CROPS

FOR THOSE WHO *HEARD* ABOUT GENETICALLY MODIFIED CROPS:
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 color will change from white to dark yellow, caused by the higher vitamin A content.

54. Do you prefer that the vitamin A in cassava be increased by conventional breeding techniques or by using laboratory techniques to genetically modify the crop?

a. Genetically Modified techniques	
b. Conventional techniques breeding	
c. Indifferent	

55. Why? _____
_____

56. It is very difficult to increase vitamin A contents in cassava through conventional breeding and GM techniques could lead to higher levels of vitamin A than conventional breeding. As a consumer, how do you feel about introducing GM cassava? Please consider all potential impacts of this type of cassava and express your viewpoint on the cultivation and consumption of GM foods in Brazil. (*Tick only one*)

1. Strongly support	
2. Support	
3. Oppose	
4. Strongly oppose	
5. Indifferent	

57. If the respondent expresses the attitude **FOR** the introduction of GM food, the reason(s) is/are: (*Tick one or more*) **(DO NOT READ OUT OPTIONS TO THE RESPONDENT)**:

1. Enhanced level of nutrients	
2. Good for the farming community.	
3. Good for the environment	
4. Price could be lesser	
5. Can't tell	
6. Others (*please specify*): _____	

58. If the respondent expresses the attitude **AGAINST** the introduction of GM food crops, the reason(s) is/are: (*Tick one or more*) **(DO NOT READ OUT OPTIONS TO THE RESPONDENT)**:

1. Does not like to experiment new kind of food	
2. It is not morally right to meddle with nature	
3. Fear of health problems	
4. Exploiting the farming community	
5. Bad for the environment	
7. Can't tell	
8. Others (*please specify*) :_____	

59. Which would you chose when the prices are identical between GM cassava with vitamin A and non-GM cassava? GM cassava ☐ Non-GM cassava ☐

V. Contingent Evaluation

60. Suppose a GM cassava, that has more vitamin A, is entering to the Brazilian markets.

1.If the GM cassava were cheaper than conventional cassava and the new price were *(currently price*_____)_____ /kg. Would you prefer to purchase it?

YE

NO

2. Suppose the price of GM cassava is lower than the conventional cassava and the new price were *(currently price* *____)_____ /kg. Would you prefer to purchase it? Yes ☐ No ☐

3. Suppose the price of GM cassava is lower than conventional cassava by and the new price were (*currently price**____) ____ /kg. Would you prefer to purchase it? Yes☐ No☐

61. What would be the maximum price you would be willing to pay for GM cassava??

1. R. ___kg. 2. Nothing ___

62. Why?

_____

VI. Conjoint Analysis

Consider the following four options of cassava that do not differ in taste or other physical characteristics from conventional cassava, except color. They also differ in terms of price and GM status. Compare these products and rank them in your order of preference. **Assign a score of 1 to the type you preferred most –**.

Option A			**Option B**			**Option C**			**Option D**
Genetically Modified			Genetically Modified			Not Genetically Modified			Not Genetically Modified
VIT A improve			No VIT A			No VIT A			No VIT A
Color: dark yellow			White			Yellow			White
Price difference from current market price (R$/kg) (*Circle*)			Price difference from current market price (R$/kg) (*Circle*)			Price difference from current market price (R$/kg) (*Circle*)			Market price
-10%	0	+10%	-10%	0	+10%	-10%	0	+10%	
Rank: _____			Rank: _____			Rank: _____			Rank: _____

GENERAL HOUSEHOLD INFORMATION

63. Religion (*Tick only one*)

1. Catholic	
2. Spirits	
3. Protestant	
4. Other (*please specify*)	

64. How many people live your household? :_____

No.	Relationship with the respondent	Sex (M/F)	Age (year)	Education (years of formal schooling)	Do you read/ write? (Y/N)	Occupation *	Do you generate income? (Y/N)
1.	Respondent						
2.							
3.							
4.							
5.							
6.							
7.							
8.							

* 1, government employer; 2, own business; 3, own farm; 4, private employed or day labor; 5, student; 6, not working; 7, other (specify).

65. Your family income is : R. _____

1. Less than a ½ minimum wage	
2. Between ½ minimum wage – 1 minimum wage	
3. Between 1 minimum wage – 11½ minimum wage	
4. Between 1 ½ minimum wages – 2 minimum wages	
5. Between 2 minimum wages – 2 ½ minimum wages	
6. Between 2 ½ minimum wages – 3 minimum wages	
7. Between 3 minimum wages – 3 ½ minimum wages	
8. Between 3½ minimum wages – 4 minimum wages	
9 More than 4 minimum wages	

66. In your house, do you have bathroom? Yes ☐ No ☐

67. Which type?: External ☐ Internal ☐ Collective ☐

68. In your house, how many bedrooms does your house have? _____

69. How many bedrooms are for sleep? _____

70. Which is the material of you house floor?

1. Cements	
2. Tile	
3. Earth	
4. Other (*please specify*):_____	

71. Do you have water? Yes ___ No___
72. Do you have electricity? Yes ___ No ___
73. Do you have a _____?

1. Own house	
2. Leased house	
3. Borrowed house?	
4. Other (please specify):_____	

74. In the <u>past 7 days</u>, how much was your household consumption on average? What was the total value in Reais? Ask for all goods consumed including: Own-produced, Bought, Gifts and Received in-kind.

	Quantity purchased (kg)	**Amount spent (R$/ month)**
1. Fresh cassava		
2. Farinha		
3. Rice		
4. Other cereals		
5. Beans		
6. Sugar		
7. Edible Oils		
8. Milk *(Liters)*		

	Quantity purchased (kg)	Amount spent (R$/ month)
9. Eggs (*Number*)		
10. Chicken		
11. Fish		
12. Mango		
13. Papaya		
14. Fruits		
15. Bread		
16. Sweets		
17. Canned food		
18. Coffee (*grams*)		
19. Alcohol (*liters*)		
20. Other Beverages (*liters*)		
21. Other food items		
22. Cooked meals bought outside (number)		
24. Cigarettes		
25. Transport/travel – long distance		
26. Newspapers		
27. Cooking gas		
28. Kerosene oil		
29. Petrol (for car, bike)		
30. Electricity charges		
31. Water access		
32. Household cleaning & Personal care (soap, shampoo, talcum, etc.)		
33. Telephone		
34. Donations (for temple or church, political parties, etc)		

75. How many [...] do you own?

1.TV	
2. Radio	
3. Refrigerator	
4. Scooter or motorbike	
5. Car	
6. Formal health insurance	

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 defense, maintenance of body linings, and cell development and reproduction. Many food crops contain vitamin A, including those that have a deep yellow or orange color 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 color will change from white to dark yellow, caused by the higher vitamin A content.

2. STAKEHOLDERS QUESTIONNAIRE

STAKEHOLDER POSITIONS TOWARD GM FOOD: THE CASE OF VITAMIN A BIOFORTIFIED CASSAVA IN BRAZIL

Please use your personal perceptions!

Objective: This study examines the factors that affect the position of stakeholders in Brazil regarding GM food, with specific emphasis on a new GM cassava with increased provitamin A content.

Genetically modified cassava with increased vitamin A. Vitamin A deficiency (VAD) is a public health problem in developing countries, where several alternatives are being used to combat this type of malnutrition. Recently, another alternative was proposed: biofortification or the increase of the micronutrient content of staple food crops through plant breeding techniques (HarvestPlus, 2007). As part of this biofortification strategy, plant breeders are in the process of developing new cassava varieties with enhanced provitamin A. These varieties will soon be released. Because the minimum desirable levels of provitamin A may not be reached in cassava through biofortification, biotechnology could be an alternative. By introducing a gene into a traditional cassava variety, scientists have engineered this new variety of cassava with increased beta-carotene (provitamin A), which the human body converts into vitamin A.

Second-generation GM crops were developed to offer direct benefits to consumers (e.g., nutrition quality). First-generation GM crops were developed to offer direct benefits to producers (e.g., insect resistance).

Questionnaire structure. The questionnaire is divided in five sections. Section 1 contains personal data; Section 2 addresses the ways people perceive GM crops; and Section 3 attempts to determine consumer attitudes toward the introduction of a new variety of GM cassava with enhanced vitamin A. Finally, Sections 4 and 5 seek to compile information about the level of trust in institutions, the perceptions about rural development strategies in Brazil, and relationships between organizations. There is also a space for comments or suggestions.

I. **Personal data**

1.1 Full name of respondent:

1.2 Sex:

F ☐ M ☐

1.3 Institution/enterprise name:

1.4 Position:

1.5 Level of education:

1.6 Disciplinary background:

1.7 Political party:

1.8 Religion:

1.9 Age:

1.10 Telephone :

1.11 City and State:

II. **Perceptions about Genetically Modified Food**
Rank the following statement (*Only tick one*):

2.1 The biosafety regulation in Brazil is clear and avoids the wrong use of GM crops in the country.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.2 Brazilian institutions do not have enough capacity to evaluate and monitor the impact of the GM crops.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.3 The production of GM crops poses serious ethical problems.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.4 GM crops are safe for the environmental if biosafety guidelines are taken in account.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.5. To consume GM food could be risky for human health.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.6 GM crops are useful to solve problems, which could not be solving by the traditional breeding approach.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.7 GM food crops could help ensure the food supply in Brazil.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.8 To become a 'GM-free country' is a good strategy to increase the competitiveness of Brazil in the global markets.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.9 GM crops could reduce some costs of producers and therefore their revenues could increase.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

2.10 GM crops developed by national research centers/enterprises have more public acceptance that those developed by multinationals.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3. Perceptions about an introduction of a GM modified cassava with more provitamin A

3.1 The second-generation of GM crops will find more public acceptance in Brazil because of the nutritional qualities which consumers may find appealing.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.2 A crop country centre of origin and diversity (for example Brazil in the case of cassava) should not use GM versions of this crop (GM cassava).

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.3 Because of the failure to approve GM food crops, consumers in Brazil could lose many nutritional benefits.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.4 It is better to continue using the current strategies to combat vitamin A deficiency (VAD) than introduce a complementary tool as a new genetically modified cassava with more provitamin A.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.5 A new GM cassava with more provitamin A could have a potential ecological risk.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.6 The GM cassava with more provitamin A is against the Brazilian culture and traditional knowledge.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

3.7 It is possible the introduction of a new cassava with more provitamin A in Brazil.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

4. Information and Trust

4.1 Please indicate your main sources of information on GM crops.

_____

_____

_____

5. Different opinions exist regarding the usefulness of GM crops in Brazilian agriculture. Please **indicate** your level of trust regarding the reliability of the information provided about GMOs. (*Rank the following institutions from 1 to 5, where 1= no confidence; 2 = low level of confidence; 3 = confidence; 4 = high level of confidence; and 5= no opinion. Assign only one score to each institution. Only mark one.)*

	Qualification
1. Non-governmental organizations (NGOs) internationals	
2. Universities	
3. Public media	
4. Public authorities (government)	
5. Industry (national)	
6. Multinationals	
7. Political parties	
8. Religious organization	
9. Consumer and producer associations	
10. International institutions (ex. FAO, WHO)	
11. National research center	

6. **Directions of Agricultural Development**

In your opinion, agricultural policies in Brazil are promoting (only choose one option):

___ Intensive production systems

___ Extensive production systems

___ Others. Please specify: _____

The main agricultural policies of the State are focused on…

Select and rank only three of the following:

___ Taxes and subsidies for producers

___ Improved links between agricultural production and agro-industry

___ Improved quality of life of poor farmers

___ Agricultural industrialization

___ Others. Please specify:_____

In your opinion, how much would you agree with the statements?

The use of modern science is required to improve agricultural production

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

Sustainable agriculture implies production systems with low or zero levels of chemical fertilizers and pesticides.

1. Totally agree	
2. Agree	
3. Disagree	
4. Totally disagree	
5. No opinion	

7. **Relationships**

Do you have a commercial, financial, or collaborative relationship with one or several of the following organizations? By *commercial*, we mean the purchase or sale or products or services; by *financial*, we mean loans or donations; and by *collaborativ*e, we mean the sharing of information, activities, and physical elements.

If you answered **YES,** please indicate the type of relationship and the frequency.

	Relationship		**Type**	**Frequency**
	Yes	**No**		
1. Non-governmental organizations (NGOs) from America			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
2. Non-governmental organizations (NGOs) from Europe			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
3. Non-governmental organizations (NGOs) from other parts			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
4. Local non-governmental organizations (NGOs)			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
5. Public media			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
6. Public authorities (government)			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
7. Industry (national)			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
8. Multinationals			Commercial: __	

			Financial: __ Cooperation: __ Other: ____	Sporadic ___ Continued ___
9. Political parties			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
10.Religious organizations			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
11. Consumer and producer associations			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
12. National research centers (i.e. Embrapa)			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___
13. International research centers (i.e. CGIAR)			Commercial: __ Financial: __ Cooperation: __ Other: _____	Sporadic ___ Continued ___

Comments and suggestions

_____

_____

SUMMARY

Micronutrient malnutrition, a widespread and serious problem especially in developing countries, can be mainly attributed to the insufficient intake of vitamins and minerals among the poor, whose diets are often dominated by starchy staple foods. Because of their higher physiological requirements, women and children are the most affected. Plant breeders of the HarvestPlus Challenge Program of the Consultative Group on International Agricultural Research are working to increase the iron, zinc, and provitamin A contents of different staple crops—an approach also referred to as biofortification. The research conducted by HarvestPlus builds mostly on conventional breeding techniques, exploiting the genetic variability within crop species. Yet there are other species where certain micronutrients are absent or only occur in very small amounts, so the use of biotechnology seems promising. Such is the case of cassava, which contains provitamin A but only at relatively low levels. Genetic modification could potentially boost the crop's provitamin A contents and, as a result, reduce more effectively the problems of vitamin A deficiency in cassava-eating populations. However, genetically modified (GM) cassava could face acceptance issues because of consumer concerns about health and environmental risks or potential ethical objections.

This study analyzes consumer preferences regarding cassava in general and public attitudes towards the introduction of GM biofortified cassava in particular, in the specific case of Brazil. A comprehensive household survey and a separate stakeholder survey have been conducted for the empirical investigation. The dissertation is structured into three articles.

Cassava is a basic staple food crop with worldwide distribution, mainly in developing countries. A fundamental source of energy for the poor, cassava grows well on marginal soils and resists pests and drought. In Latin America, Brazil is the largest cassava producer and consumer. The crop is especially important in the northeastern (NE) part of the country, where poverty and malnutrition rates are higher than in the rest of the country. However, despite the crop's dietary importance, relatively little is known about consumer preferences, which holds true not only for Brazil but also for other developing countries. Understanding consumer preferences is crucial for technology and market development, especially in the context of provitamin A biofortification, as this entails a yellow-colored cassava root. The first article, titled "Consumer Preferences for Cassava Characteristics in Pernambuco, Brazil", addresses this research gap. Consumer

preference for different cassava attributes are analyzed using household survey data and econometric techniques. A hedonic price model is specifically developed to estimate the values that consumers place on specific product attributes. Results show the most important characteristics for local consumers are ease of peeling, time of cooking, and texture; however, root color and size as well as market location are other relevant attributes in determining price.

The second article, titled "Consumer Acceptance of Second-Generation GM Foods: The Case of Biofortified Cassava in the Northeast of Brazil", examines whether consumers would appreciate provitamin A biofortification and accept GM cassava. For this purpose, stated preference data, collected as part of the household survey, are used. Findings suggest that attitudes towards GM biofortified cassava are generally quite positive among local consumers. Three-quarters of all respondents in the survey said they would support the introduction of this new technology. Using contingent valuation techniques, consumers were shown to be 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. In addition, a contingent ranking choice experiment was used to better understand the trade-offs between different cassava characteristics and estimate the partial willingness to pay (WTP) for each relevant attribute. For the provitamin A attribute alone, the average consumer is willing to pay a large premium of 160%. However, a discount is required for the color change of cassava from white to yellow (-29%), and an additional discount results from the fact that the cassava is genetically modified (-61%). These are important findings for biofortification research programs that have to make choices between conventional and GM breeding techniques. It is noted that a significantly positive WTP does not imply that GM provitamin A 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 should be sought to enable easy access. Hence, the WTP survey is a tool to better understand consumer attitudes rather than an approach to develop a pricing strategy for a new commercial product.

The third article, titled "Stakeholder Positions toward GM Food: The Case of Vitamin A Biofortified Cassava in Brazil", gathers experiences from around the world and shows that stakeholder positions can crucially influence the efficiency of GM regulatory approaches and the success of new technologies. This research builds on a survey of a large range of local stakeholders. Overall, stakeholder perceptions about

GM foods are relatively positive in Brazil. Statistical analysis shows that three groups of stakeholders can be distinguished: those in favor of GM crops, those against, and those that have a more or less neutral position. Representatives of local and multinational industries and those of several governmental entities belong mostly to the first group; international and national NGOs form the second group, while scientists are mostly found in the third group. Information sources and institutional/personal relationships influence individual stakeholder positions, as do socio-demographic characteristics, such as the level of education and age. An important result is also the high level of trust that stakeholders in Brazil have, in general, in the country's research and academic sectors. Therefore, taking into account the relevance of information and the role played by the research sector, an effective system of distributing GM crop information via government agencies and/or public media is necessary to complement the knowledge of consumers so that they can make their own informed decisions.

Overall, the results bode well for the introduction of GM provitamin A cassava in Brazil, confirming earlier findings from developed countries that show that second-generation GM crops with direct consumer benefits are valued more positively than first-generation technologies that only involve agronomic crop traits. However, some caution is warranted regarding the interpretation of results, as much of the analysis builds on stated preference data, which might be associated with a certain degree of hypothetical bias.

ZUSAMMENFASSUNG

Öffentliche Akzeptanz von gentechnisch verändertem Provitamin A Maniok in Brasilien

Mikronährstoffmangel ist ein weit verbreitetes Problem, vor allem in den Entwicklungsländern. In armen Bevölkerungsgruppen resultiert er in erster Linie aus einer unzureichenden Aufnahme von Vitaminen und Mineralien, da die Ernährungsmuster häufig einseitig auf stärkehaltigen Grundnahrungsmitteln beruhen. Aufgrund des höheren physiologisch bedingten Bedarfs sind Frauen und Kinder am stärksten betroffen. Im *HarvestPlus* Programm der *Consultative Group on International Agricultural Research* arbeiten Pflanzenzüchter an einer Steigerung des Eisen-, Zink- und Provitamin A-Gehalts in verschiedenen Grundnahrungsmitteln – ein Ansatz, der auch Biofortifikation genannt wird.

Die Forschung im HarvestPlus Programm baut größtenteils auf konventionelle Züchtungsmethoden auf. Es gibt jedoch auch Kulturarten, in denen bestimmte Mikronährstoffe komplett fehlen oder nur in sehr geringen Mengen vorkommen, so dass der Einsatz biotechnologischer Verfahren vielversprechender erscheint. Ein typisches Beispiel ist Maniok, der kaum Provitamin A enthält. Der Einsatz der Gentechnik könnte den Gehalt an Provitamin A beträchtlich erhöhen und so dazu beitragen, Ernährungsprobleme zu reduzieren. Andererseits könnte gentechnisch veränderter (GV) Maniok zu Akzeptanzproblemen in der Bevölkerung führen – etwa aufgrund von Verbraucherängsten vor Gesundheits- und Umweltrisiken oder potenziellen ethischen Bedenken.

In dieser Dissertation werden Bevölkerungspräferenzen in Bezug auf Maniok im Allgemeinen, und auf biofortifizierte GV Sorten im Speziellen, in Brasilien analysiert. Hierzu wurden eine umfassende Haushaltsbefragung und eine Befragung von Vertretern unterschiedlicher Interessengruppen durchgeführt. Maniok ist in vielen Entwicklungsländern ein wichtiges Grundnahrungsmittel. Die Wurzelfrucht stellt vor allem für arme Menschen eine wesentliche Energiequelle dar. In Lateinamerika ist Brasilien das größte Erzeuger- und Verbraucherland. Maniok ist besonders im Nordosten Brasiliens wichtig, da dort Armuts- und Fehlernährungsraten höher sind als im Rest des Landes. Trotz der großen Bedeutung von Maniok, ist sowohl in Brasilien als auch in anderen Entwicklungsländern relativ wenig über Verbraucherpräferenzen

bekannt. Solche Kenntnisse wären allerdings für die Technologie- und Marktentwicklung wichtig. Dies gilt besonders für Provitamin A Biofortifikation, da diese statt der üblichen weißen, eine gelbe Farbe der Maniokwurzel zur Folge hat. Die Dissertation ist in drei Artikel strukturiert.

Der erste Artikel mit dem Titel "Verbraucherpräferenzen für Maniokeigenschaften im Pernambuco, Brasiliens" verfolgt das Ziel, diese Forschungslücke zu verringern. Verbraucherpräferenzen für verschiedene Maniokeigenschaften werden mit Hilfe der Daten aus der Haushaltsbefragung und ökonometrischen Methoden analysiert. Speziell wird ein hedonistisches Preismodell entwickelt, um die Werte zu schätzen, die die Verbraucher bestimmten Produktattributen beimessen. Die Ergebnisse zeigen, dass Schälleichtigkeit, Kochzeit und Wurzelkonsistenz die wichtigsten Eigenschaften für lokale Verbraucher sind. Dennoch sind auch die Farbe, Wurzelgröße und Marktlokalität weitere relevante Attribute, die den Preis bestimmen.

Der zweite Artikel "Verbraucherakzeptanz der zweiten Generation von GV Nahrungsmitteln: Das Beispiel von biofortifiziertem Maniok im Nordosten Brasiliens" untersucht, ob Verbraucher Provitamin A Biofortifikation schätzen und GV Maniok akzeptieren würden. Für diesen Zweck werden erklärte Verbraucherpräferenzdaten, die ebenfalls im Rahmen der Haushaltsbefragung erhoben wurden, verwendet. Die Ergebnisse zeigen, dass die Einstellung zu GV biofortifiziertem Maniok bei lokalen Verbrauchern insgesamt relativ positiv ist. Drei Viertel aller Befragten gaben an, dass sie die Einführung dieser neuen Technologie befürworten. Mit Hilfe der kontingenten Bewertungsmethode wird gezeigt, dass Verbraucher bereit sind, eine durchschnittliche Preisprämie von 64% für GV biofortifizierten Maniok zu bezahlen. Dies erscheint zwar recht viel, aber nicht völlig unrealistisch, wenn man in Betracht zieht, dass Vitamin A Mangel im Nordosten Brasiliens ein weit verbreitetes und gravierendes Gesundheitsproblem ist.

Zusätzlich wurde ein Choice-Experiment durchgeführt, um eventuelle Zielkonflikte zwischen unterschiedlichen Maniokeigenschaften besser zu verstehen und die Zahlungsbereitschaft für Einzelattribute zu schätzen. Für das Attribut Provitamin A allein ist der durchschnittliche Verbraucher bereit, eine stattliche Prämie von 160% zu bezahlen. Jedoch verringert sich die Zahlungsbereitschaft durch die Gelbfärbung um 29 Prozentpunkte, und die GV Eigenschaft führt zu einer weiteren Reduktion um 61 Prozentpunkte. Dies sind wichtige Ergebnisse für Biofortifikations-

Forschungsprogramme, in denen zwischen konventionellen und gentechnischen Züchtungsmethoden gewählt werden muss. Es ist zu betonen, dass eine signifikant positive Zahlungsbereitschaft nicht bedeutet, dass Provitamin A Maniok tatsächlich mit einem Preisaufschlag verkauft werden wird. Da die Technologie durch den öffentlichen Sektor entwickelt wird, sollte der Preis möglichst niedrig sein, um armen Menschen als Hauptzielgruppe den Zugang zu ermöglichen. Insofern dient die Zahlungsbereitschaftsanalyse nicht zur Entwicklung einer kommerziellen Preisstrategie, sondern ausschließlich als Instrument, um Verbrauchereinstellungen besser zu verstehen.

Der dritte Artikel trägt den Titel "Die Einstellung unterschiedlicher Interessengruppen zu Genfood: Das Beispiel von biofortifiziertem Provitamin A Maniok in Brasilien". Internationale Erfahrungen zeigen, dass Interessengruppen und die Einstellung unterschiedlicher Beteiligter die Effizienz von Regulierungsprozessen und den Erfolg biotechnologischer Innovationen entscheidend beeinflussen können. Diese Studie baut auf einer Befragung von Vertretern unterschiedlicher Organisationen in Brasilien auf. Die Ergebnisse zeigen, dass die Einstellung zu Genfood insgesamt relativ positiv ist. Dennoch gibt es deutliche Unterschiede. Statistische Analysen ergeben, dass drei Gruppen unterschieden werden können: Befürworter von Genfood, Gegner und solche, die eine eher neutrale Position verfolgen. Vertreter von nationalen und multinationalen Firmen und einige Regierungsbehörden gehören größtenteils der ersten Gruppe an. Nationale und internationale NGOs bilden die zweite Gruppe, während Wissenschaftler größtenteils in der dritten Gruppe zu finden sind. Informationsquellen und persönliche sowie institutionelle Beziehungen, ebenso wie soziodemografische Eigenschaften (z.B. Ausbildungsgrad, Alter), beeinflussen die individuelle Einstellung. Bezeichnend ist das große Vertrauen, das Forschung und Wissenschaft in Brasilien über die Gruppierungen hinweg genießen. Ein breites Informationssystem, welches neben dem Forschungssektor auch Regierungsbehörden und öffentliche Medien einschließt, erscheint wichtig, damit die Verbraucher in die Lage versetzt werden, eigene fundierte Entscheidungen hinsichtlich Genfood treffen zu können.

Die Ergebnisse der Dissertation geben Grund zur Annahme, dass GV Provitamin A Maniok in Brasilien weit verbreitet akzeptiert und somit ohne große Widerstände in der Bevölkerung eingeführt werden könnte. Sie bestätigen auch frühere Studien aus Industrieländern, die zeigen, dass GV Pflanzen der zweiten Generation, d.h. solche mit

direkten Vorteilen für die Verbraucher, insgesamt positiver eingeschätzt werden als GV Pflanzen der ersten Generation, die lediglich agronomische Vorteile bieten. Allerdings sollten die konkreten Ergebnisse mit einiger Vorsicht interpretiert werden, weil die Analysen überwiegend auf erklärten und nicht auf tatsächlich offen gelegten Präferenzdaten beruhen, so dass ein gewisser hypothetischer Bias nicht vollständig ausgeschlossen werden kann.