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Enhanced GM Foods: Are Consumers Ready to Pay for the Potential Benefits of Biotechnology?

The present study analyzes and compares willingness to pay estimates for different genetic modifications in a tomato plant. Results suggest that consumers are ready to pay the highest premiums for modifications which increase the tomato flavor or enhance the nutritional value. However, these premiums are still fairly small, reflecting the general difficulty of opening new markets for products that consumers may perceive as not completely safe.

INTRODUCTION

Literature in the general topic area of consumer response toward genetically modified (GM) crops and foods is becoming increasingly important. Consumer attitude studies have focused on the analysis of consumer response toward *current* GM products, which, in most cases, offer benefits only to producers. However, genetic modification purposes are changing, and the second generation of GM crops will offer benefits to consumers. The biotech industry hopes that current consumer concerns will be eliminated if this second generation of GM crops reports clear benefits to consumers.

In this study, we look at GM products that offer potential improvements over conventional products. The impact of beneficial attributes associated with new food technology has important economic and marketing implications. Therefore, a better understanding of consumer attitudes and behavior toward GM food products is essential for designing new market strategies and information policies in the area of *enhanced GM products*, which recently are becoming very popular.

In general, consumer adoption of new GM products depends on whether the benefits outweigh the potential risks (see Bredahl 2001; Bredahl,

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Grunert, and Frewer 1998). Bredahl, Grunert, and Frewer (1998) developed different models of consumer behavior toward GM foods. Following these models, we assume that both perceived risks and perceived benefits toward a particular GM product are mixed, and influenced by other general consumer attitudes (which are included via respondents' sociodemographics and ethical attitudes toward GM manipulation). This combination of factors leads to determining the final attitude toward genetic engineering in food production. In our application, this general consumer attitude toward genetic engineering will translate into price premiums that consumers may or may not be willing to pay for GM-enhanced foods.

There are several known potential risks associated with GM crops and foods. These include, but are not necessarily limited to, health issues (such as allergenicity, increased toxins, antibiotic resistance, and unknown consequences to humans) and environmental issues (such as effects on nontarget organisms, crop-to-crop cross-pollination, crop-to-weed pollination, and development of pest resistance to insecticides) (Feldmann, Morris, and Hoisington 2000). These potential risks, however, do not always translate into perceived risks by consumers. In the case of biotechnology products, Grobe, Douthitt, and Zepada (1999) show that risk perceptions are significantly affected by consumer sociodemographics, such as age, gender, and education.

Alternatively, benefits associated with GM manipulation are also various, depending on the final use or goal of the product. Some of the most common benefits include an increase in nutritional qualities, the reduction of pesticide applications, and increase in shelf life of the product.

Few consumer economic studies have looked at the impact of benefit perceptions of GM food on information-seeking or purchasing behavior. This paper will add to the consumer economic literature about GM products in the United States, as a study of willingness to pay (WTP) for beneficial attributes associated with this new type of food technology. This differs from the existing body of research about GM products, as most prior consumer acceptance and demand studies have looked at WTP for non-GM products (see for example, Chern et al. 2003; Moon and Balasubramanian 2003) or willingness to accept compensation to buy them (see Grimsrud et al. 2004). Our study explores the idea that consumers may be willing to pay a premium for a GM product that offers a direct personal benefit.

In this paper, we compare consumers' WTP for different types of genetic modifications in a tomato plant. We conclude that the highest premiums can be obtained for modifications which enhance the tomato flavor or nutritional value. However, these premiums are still fairly small, reflecting the general difficulty of opening new markets for products that consumers may perceive as not completely safe.

LITERATURE REVIEW

There are many studies dealing with consumers' response to differentiated products, although only a handful address the issue of WTP for GM or GM-free food products. Existing studies have elicited WTP for genetically modified (GM)–free products by using either contingent valuation methods or experimental auction methods.

Contingent valuation methods are used by Loureiro and Hine (2002), with the objective of determining consumer WTP for a labeled, value-added potato that could be marketed as organic, GM free, or Colorado grown. They conclude that consumers would pay higher premiums for potatoes labeled as Colorado grown than for GM-free or organic potatoes. Lusk, Roosen, and Fox (2003) estimate premiums for beef from cattle not fed GM corn in the United States, France, Germany, and the United Kingdom. They conclude that premiums for non-GM-fed beef are much higher in Europe (and especially in France) than in the United States. Moon and Balasubramanian (2001, 2003) use a survey instrument including contingent valuation questions to assess consumer willingness to pay a premium for non-GM breakfast cereals. They find that in both the United Kingdom and the United States, risk and benefit perceptions clearly translate into purchasing intentions and behaviors as measured with WTP.

Consumers' acceptance of GM food and WTP for non-GM vs. GM products was the topic of interest in two recent papers by Chen and Chern (2002) and Chern et al. (2003). Their research provides WTP estimates based on consumers' attitude toward GM foods and other characteristics using contingent valuation techniques. Chen and Chern (2002) present results from an Ohio survey, which is part of the larger, multicountry study discussed by Chern et al. Regression results for the three food products (vegetable oil, salmon, and corn flake breakfast cereal) show that variables related to attitude, perception, labeling, demographics, and price have significant effects on consumer choices between GM and non-GM food products in the United States. Additionally, this research indicates that consumers demand significant price reductions for GM products. Nevertheless, the researchers conclude that the "opposition against GM foods is reduced when some benefits associated with them are introduced into the questions suggesting that GM foods have a potential to become more popular."

Therefore, consumers' acceptance of GM foods may be significantly different if the food products can offer direct, personal benefits as also indicated by Moon and Balasubramanian (2003). In an extension of their earlier study, Moon and Balasubramanian (2003) find that consumers who perceive GM technology as beneficial are less likely to pay a premium for

nonbiotech foods. Thus, they conclude that promoting beneficial attributes associated with biotechnology could offset consumers' risk perceptions. This conclusion also serves as motivation for the present paper.

The interest in this issue has prompted researchers all around the world to analyze consumer reactions to GM products, which may be perceived as products of ambiguous nature (combining both risks and benefits). In this regard, Grunert et al. (2000) find that GM confections with low-calorie content that could be consumed by diabetics were valued by consumers. Boccaletti and Moro (2000) look at consumer acceptance of enhanced GM foods in a sample of Italian consumers, concluding that income and the level of knowledge affect consumer response toward these new technologies, although they do not explicitly calculate mean WTP values for any of the different GM manipulations. Bech-Larsen and Grunert (2000) contribute to these international case studies, employing conjoint analysis to analyze how health benefits associated with GM manipulations in hard cheese change consumer perceptions in Nordic countries. Their results show that resistance to such products could be toned down if certain benefits were made clear and if consumers could actually taste the product before answering the questions. More recently, Burton and Pearse (2003) concluded that a large percentage of consumers who view cholesterol as a significant issue are prepared to pay a premium to purchase a bottle of beer with increased antioxidants, which reduce cholesterol levels. In New Zealand, Fortin and Renton (2003) analyzed consumer reactions to GM manipulation in bread and milk, concluding that the presence of additional product benefits (in their study, increased longevity) resulting from the GM manipulation does not offset the negative views associated with these new products.

In spite of the fact that literature in this area has grown rapidly in recent years, few empirical studies provide WTP estimates for GM-enhanced products. Further, to our knowledge, these previous studies are not directly applicable to U.S. consumers. The study of U.S. consumer reactions toward enhanced GM products is interesting, since U.S. consumers have been more receptive to these new food products than many other consumers around the world. For example, results obtained from the consumer survey undertaken by the International Food Information Council (August 2002) show an overall consumer support of biotechnology and an increase in recognition of specific potential benefits. In particular, 71% of the sample population, which was representative of the U.S. population, said they were likely to buy produce enhanced by biotechnology to require fewer pesticide applications. Additionally, 54% indicated a willingness to purchase the produce enhanced to taste better. Furthermore, 61% of respondents expected to

benefit from biotechnology over the next five years. In Europe, on the other hand, the *Eurobarometer* opinion pool published by the European Commission in December 2001 showed that 94.6% of the surveyed European Union citizens want *the right to choose* what product they are buying; 70.9% simply do not want GMOs, and 59.4% say that GMOs could have negative effects on the environment.

Thus, keeping in mind this background information and previous research, the present study complements and extends in dimension the previous results, comparing WTP estimates and consumers' response toward different GM product attributes in a sample of U.S. consumers. The product selected in this application is a fresh tomato. Given that this is a staple food, we can safely assume that any regular consumer is familiar with the original product. The attributes considered in this analysis of a GM tomato include enhanced nutritional value, pesticide reduction, increased food shelf life, increased profits for farmers, and enhanced flavor. The information gathered from this study should reveal consumer preferences toward these types of modifications and be helpful to policy makers.

DATA

Data were gathered using a mail survey in the western states of the United States, which included the states of Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Oregon, Utah, Washington, and Wyoming. A sample of 1,000 participant households was drawn from a mailing listing purchased from Survey Sampling, Inc., a leader in the science of sampling methodology and research quality. This listing was compiled from the white page directories and supplemented with a variety of other sources such as Department of Motor Vehicles information, voter info, census data, and school records. Thus, it was expected that this initial listing was representative of the current U.S. Census.

Upon receiving the listing of 1,000 households, scripted calls were placed to each household. The purpose of the call was to determine if someone in the household would be willing to participate in the study by completing a mail survey. Unfortunately, only half of the sample was reached via phone call because of the use of phone call screening devices. Consequently, the survey was sent to all households that showed interest in participating and those that were not initially reached via phone. In total, it was sent to 680 households.

Before the survey was sent off, a pretest was conducted in two different locations in the states of Colorado and California. After making slight modifications using the information gathered in the pretest, the final survey was

sent out in a six-page booklet format, with a cover letter explaining the project, and a prepaid return envelope. The survey included four different sections. In the first section, different warm-up questions related to general knowledge and information about risks and benefits associated with GM foods were presented to the respondents. The level of consumer concerns with social/ethical, health, and environmental issues surrounding genetic modifications was obtained in section two. The third section contained the elicitation of WTP for different GM processes in the tomato plant. The last section included questions related to sociodemographics variables.

In total, 164 responses were collected. The respondents' average age was between 45 and 49 years, with a mean education that included junior college. Further, 64.6% were married, and 24.69% of all respondents had children under the age of 18 years living in their household. The average household size was about 2.5 members, and the average household income was contained in the bracket between $50,000 and $59,999 (about $55,500) for the 2001 fiscal year.[1] Summary statistics are presented in Table 1. Comparing our sociodemographic figures with the U.S. Census (U.S. Census Bureau, 2000), as in Table 2, we conclude that our sample is considerably older (the median age being about 50–54 years for the sample and 35.7 years for the U.S. population) and more educated. When compared with the U.S. Census, the current sample has also lower percentages of females and households with children under 18 years of age. Thus, we acknowledge that this sample has different sociodemographic characteristics than the U.S. population. Although research conducted by Edwards and Anderson (1987) found significant differences between respondents and nonrespondents, unfortunately, in our study, we do not have any information regarding the nonrespondents. Consequently, we cannot assess the impact of sample selection bias in our WTP estimates.

It is likely that some degree of sample selection bias is inherent to the process of data collection. Thus, respondents who were more interested in the topic of GM crops and food products, and had more time available, were probably more likely to participate in the survey. Since data collection was done via mail survey, it is also common that the sample of respondents has a higher education level than the population of reference. These features are common to many other empirical studies and consumer surveys (see for example, Lusk, Roosen, and Fox 2003) and related to the fact that economic inducements are not always used, or if used, they are not always sufficient to motivate participation of people with a higher opportunity cost of time. In the current study, participation rate was estimated to be about 25% of the total number of surveys mailed, which is fairly high for a mail survey without employing any economic inducement.

TABLE 1
Sociodemographic Characteristics of the Sample[a]

	Description	Mean	SD	Cases
Age	1 = Under 20 2 = 20–24 3 = 25–29 4 = 30–34 5 = 35–39 6 = 40–44 7 = 45–49 8 = 50–54 9 = 55–59 10 = 60+ years	7.97 (50,819)[b]	1.9999 (10,469)	160
Gender	1 = Female 0 = Otherwise	0.4161	0.4944	161
Education	1 = Elementary school or less 2 = Some high school 3 = High school graduate 4 = Some college 5 = Junior college graduate 6 = 4-Year university graduate 7 = Postgraduate work 8 = Any other education (recoded depending on the attainment level)	5.1949	1.6000	161
Income	1 = Under $20,000 2 = $20,000–$29,999 3 = $30,000–$39,999 4 = $40,000–$49,999 5 = $50,000–$59,999 6 = $60,000–$69,999 7 = $70,000+	5.1372 (53,720)[b]	1.9366 (17,376.2)	153
Household members	Continuous variable	2.5093	1.3468	161
Children under 18 at home	1 = Yes 0 = No	0.2469	0.4325	161
Manipulation	Likert scale variable; 1 is preserving natural species at all costs, and 10 is manipulating species for a benefit at all costs	4.794	2.588	155
Concern	Average stated concern of social, environmental, and health risks associated with GM manipulation	9.236	5.600	162

[a]Due to the presence of some missing values in some variables included in the regressions, the means of the explanatory variables included in the regression differ a bit from the ones presented in this table.
[b]Means employing the variable midpoints.

TABLE 2
Comparison of Sample Sociodemographic Variables vs. U.S. Population

Sociodemographics	Sample	U.S. Population[a]
% Female	41.6	51.19
% Household with children under 18 years of age	24.69	35.62
% Bachelor's degree or higher	52.8	25.5[b]
Mean income	$53,720	$56,360
Median age, years	8 (50–54)	35.7

[a]Source: Consumer Survey and U.S. Census Bureau, Census 2001.
[b]Persons of 25 years and over, 2001.

MULTIPLE BOUNDED PROBIT ANALYSIS

The survey elicited WTP using a payment card format. Alberini (1995) showed that the interval data model is often superior to the bivariate model of a dichotomous question with follow-up. The crucial valuation question used in the survey was as follows: Assuming that there is no known risk (for humans or for the environment), what percentage premium, if any, would you be willing to pay over the initial price ($2.29 per pound) for a tomato that has been modified to benefit you in the following ways: enhanced nutritional value, pesticide reduction, increased food shelf life, increased profits for farmers, and enhanced flavor? Consumers were presented with the following bid intervals: not willing to pay (0% premium), 1%–5% premium, 6%–10% premium, 11%–15% premium, 16%–20% premium, 21%–25% premium, 26%–30% premium, and over 30% premium (see Appendix). Frequency distribution of responses is presented in Table 3. Employing these data, a classical parametric WTP estimate for each type of GM tomato was estimated.

Cameron and Huppert (1989) developed a maximum likelihood framework that suits data gathered using a payment card. This multiple bounded probit model has been frequently used in the environmental economics and marketing literatures (see Cameron 1988).

To motivate this model, we assume that the respondent's true valuation or WTP follows a linear function,[2] which lies within the interval defined by the thresholds (t_{li}) and (t_{ui}) of the payment card. It's generally presumed that the expected WTP, $E(\text{WTP}_i|x_i)$, is some function of the explanatory variables and associated parameters, $g(x_i,\beta)$, for which a linear-in-parameters form is computationally convenient. In the simplest case, we will have:

$$\text{WTP}_i = x_i'\beta + \varepsilon_i, \tag{1}$$

TABLE 3
Percentages and Distribution of the WTP Responses for the Different Attributes

	Percentage Response by Interval				
Intervals	WTP for enhanced nutritional value	WTP for pesticide reduction	WTP for increased food shelf life	WTP for increased profits for farmers	WTP for enhanced flavor
WTP = 0 Not willing to pay	32.87	38.10	43.06	46.53	32.43
WTP 1%–5% premium	28.67	27.21	26.39	24.31	25.68
WTP 6%–10% premium	16.78	16.33	14.58	14.58	15.54
WTP 11%–15% premium	7.69	6.80	4.17	5.56	10.81
WTP 15–20% premium	6.99	6.12	6.25	3.47	8.78
WTP 21%–25% premium	3.50	2.72	3.47	2.08	3.38
WTP 26%–30% premium	0.70	0.68	0.69	0.69	1.35
WTP >30% premium	2.80	2.04	1.39	2.78	2.03
	$n = 143$	$n = 147$	$n = 144$	$n = 144$	$n = 148$

where WTP_i is an indicator variable for the latent (nonobservable) WTP* value.

In the specification at hand, the limited dependent variable takes the following values: $WTP_i = 1$ if $WTP^* \leq 0$, $WTP_i = 2$ if $1 \leq WTP^* \leq 5, \ldots,$ $WTP_i = 8$ if $WTP^* > 30$.

Further, x_i' is a vector of explanatory variables that potentially affect consumers' WTP for different GM tomatoes, and β is the vector of corresponding coefficients. The vector of explanatory variables includes sociodemographic characteristics of the respondent, such as age, the presence of children in the household, income level, education, gender, and some GM attitude variables, which include views on manipulation of natural species and concerns related to GM technologies. The final component of the model, ε_i is an error term normally distributed with mean zero and standard deviation σ.

We can standardize each pair of interval thresholds for WTP_i, expressing the probability that the true valuation lies between both thresholds as

$$\Pr(WTP_i \subseteq (t_{li}, t_{ui})) = \Pr((t_{li} - x_i'\beta)/\sigma < z_i < (t_{ui} - x_i'\beta)/\sigma)), \quad (2)$$

where z_i is the standard normal random variable. Therefore, after this transformation, the probability expressed in equation (2) can be rewritten as the difference between two standard normal cumulative distribution functions and expressed as

$$\Pr(WTP_i \subseteq (t_{li}, t_{ui})) = \Phi(z_{ui}) - \Phi(z_{li}). \quad (3)$$

Thus, the likelihood function is given as:

$$\text{Log } L = \sum_{i=1}^{n} \log[\Phi(z_{ui}) - \Phi(z_{li})]. \tag{4}$$

The estimation of this likelihood function makes it possible to draw conclusions about how consumers value perceived benefits of different GM tomatoes and how views on manipulation vs. preservation of species, information levels, and consumers' sociodemographic characteristics affect their WTP. Estimation of this likelihood function was conducted using the software package LIMDEP, applying the GROUPED DATA command.

EMPIRICAL SPECIFICATION

The WTP (equation 1) has been estimated independently for each genetic modification (enhanced nutritional value, pesticide reduction, increased food shelf life, increased profits for farmers, and enhanced flavor) using a common set of explanatory variables. This was done to facilitate a comparison among the different sociodemographic factors that characterize the niche markets for each potential genetic modification of a tomato. The final specification of the WTP equation is as follows:

$$\begin{aligned} \text{WTP}_i = {} & \beta_0 + \beta_1 \text{Children}_i + \beta_2 \text{Income}_i + \beta_3 \text{Education}_i + \beta_4 \text{Age}_i \\ & + \beta_5 \text{Female}_i + \beta_6 \text{Manipulation}_i + \beta_7 \text{Concern}_i + \varepsilon_i, \end{aligned} \tag{5}$$

where Children is a dummy variable that represents the presence of children under 18 years of age in the household, Income represents the household income (in thousands of dollars), Education is the respondent's educational level (from elementary school to postgraduate work), Age is the respondent's age, and Female is a dummy variable that represents a female respondent.

In addition to these sociodemographic characteristics, other variables containing consumers' perceptions and concerns regarding GM technologies were included, which were found to be statistically significant in previous studies. As an example, in their investigation of U.S. consumers' acceptance of GM corn flakes, Baker and Burnham (2001) found that cognitive variables (opinions, beliefs, knowledge) have a great influence on consumer preferences. Thus, the role played by perceived concerns associated with biotechnology is crucial and should be considered in order to assess consumer response toward these new products (Frewer 2000).

Consequently, in the above specification, Concern is a variable that represents the mean of environmental, health, and other social and ethical concerns[3] stated by each survey participant. Manipulation is a Likert scale variable ranging from 1 to 10, with 1 representing the preference of preserving natural species at all costs, and 10 representing manipulating natural species in order to get a benefit at all costs. Finally, ε_i denotes a normally distributed error term. Variable definitions and summary statistics are presented in Table 1. (See the Appendix for actual questions used in the survey.)

RESULTS

As reported in Table 3, the frequencies or percentages associated with the WTP intervals for the different attributes of GM tomatoes decreased at the higher thresholds. As demand theory would predict, the higher the bid amount (or in this case, the amount contained in the interval of the payment card), the lower the percentage of affirmative responses to the WTP question. In general, many respondents were not willing to pay any amount for these beneficial attributes. For example, over 46% are not willing to pay for increased profits for farmers. This large proportion of zero responses corresponds with consumers who dislike GM foods and consequently are not willing to pay any premium for these enhanced GM products.

Regressions reflecting sociodemographic factors and perceived risks or concerns affecting WTP values are presented in Table 4. All coefficient estimates carry the expected signs, and the associated likelihood ratio tests reject the corresponding null hypothesis that the included coefficients are equal to zero; thus, there is statistical evidence of the overall significance of the empirical model.

With respect to the regression of WTP for enhanced nutritional value, the explanatory variables denoting Income, Age, and attitudes toward Manipulation carry statistically significant coefficients, whereas Income and the Manipulation variable both have positive effects on the WTP estimates. The variable Age, on the other hand, carries a negative coefficient. The significance of the Manipulation coefficient is also replicated in the other four WTP equations. Other variables, such as the respondent's Education and Concerns toward biotechnology, are not statistically significant. Thus, it seems that the perceived benefits due to the modification outweigh the perceived risks associated with the technology.

With regard to the WTP for pesticide reduction regression, the variables Income and Manipulation carry statistically significant and positive coefficients. Thus, both higher income levels and acceptance of manipulation of

TABLE 4
WTP Regressions for Different Genetic Modifications

	WTP for a Tomato with Enhanced Nutritional Value		WTP for a Tomato with Reduced Dose of Pesticides		WTP for a Tomato with Increased Shelf life		WTP for a Tomato Modified to Increase Profits for Farmers		WTP for a Tomato Modified to Enhance Flavor	
	Coefficient	*p* value	Coefficient	*p* value	Coefficient	*p* value	Coefficient	*p* value	Coefficient	*p* value
Constant	6.81829	.387607	2.30313	.755174	1.17893	.884045	−4.04607	.632053	1.32048	.856893
Children	−1.22373	.613735	−1.02077	.654586	−0.14457	.953478	−2.98129	.254886	1.43215	.529377
Income	0.096416*	.08888	0.104883*	.055716	0.098826*	.095693	0.122882**	.046339	0.125192**	.01781
Education	−0.34052	.584692	−0.89308	.133758	−0.9944	.123892	−1.18101*	.078435	−0.83768	.156284
Age	−0.18697**	.048235	−0.13094	.146879	−0.07683	.434323	−0.0629	.531554	−0.09005	.317412
Female	0.073741	.970113	2.50658	.181177	1.6388	.421487	4.4602**	.036166	1.96448	.292439
Manipulation	1.24461**	.003169	1.25783**	.001274	1.2766**	.002404	1.53133***	.000522	1.41832***	.000178
Concern	−0.33034	.112167	−0.14383	.451152	−0.33592	.113043	−0.17573	.413281	−0.35389*	.056851
Sigma	9.86407***	.00000	9.39919***	.00000	9.99223***	.00000	10.2149***	.00000	9.46684***	.00000
Log-likelihood function	−213.951		−209.4320		−200.4164		−190.8139		−257.0441	
Restricted log-likelihood (constant only)	−246.1903		−239.7697		−225.2187		−220.3742		−222.6106	
Likelihood ratio test	64.4786		60.6754		49.6046		59.1206		60.867	
Pseudo-R^2	0.1309		0.1265		0.1101		13.4131		13.396	

***, **, and * represent statistically significant coefficients at $\alpha = .001$, $\alpha = .05$, and $\alpha = .1$, respectively. The critical $\chi^2_{7(0.005)}$ is 20.2777. Since the likelihood ratio test values are greater than this critical value, there is statistical evidence of the joint significance of the included coefficients.

species have a positive relationship with the dependent variable. The variable Children was not statistically significant in any of the five WTP regressions. This is an interesting finding, since we could hypothesize that the presence of children in a household may make a consumer less likely to trust new food technology. This may reflect the fact that to a certain extent the negative perceptions toward GM foods are mitigated when offering a potential benefit to consumers. Other studies (i.e., Huffman et al. 2003) have found similar nonsignificant relationships of the typical sociodemographic variables. The increased shelf life WTP regression is mainly explained by the significance of the same two explanatory variables, as in the previous regression. Again, both Income and the consumer's view of manipulating natural species (Manipulation) carry positive and statistically significant signs.

The WTP equation for genetic modification that provides higher profits to farmers seems to be explained by four sociodemographic and attitude variables (Income, Education, Gender, and Manipulation). Thus, as in previous research, females may be more altruistic, since they are more likely to pay a premium without explicitly receiving any direct benefit from the product. All indicated variables have positive and statistically significant effects on the WTP. Finally, in the WTP equation for the enhanced flavor attribute, three variables are statistically significant: the Income and Manipulation variables, both of which have a positive and statistically significant effect similar to the previous equations, and the variable Concern, which carries a negative and statistically significant effect.

Mean WTP for the different attributes were estimated using the model results presented in Table 4 and evaluating the coefficients at the corresponding means of the explanatory variables. Confidence intervals were estimated using the formula presented by Cameron (1991). The different premiums carried by the different attributes and their corresponding 95% confidence intervals are presented in Table 5. According to our results, GM tomatoes with enhanced flavor carry the highest potential premium (3.81% or the equivalent of 8.73 cents per pound) over the initial price of $2.29 per pound. Given the product used in this analysis, the tomato, it is not really surprising that consumers are most interested in better-flavored tomatoes rather than other characteristics associated with healthier tomatoes (such as higher nutritional content and reduced doses of pesticides). This may be due to the fact that tomatoes are such a seasonal product and that it is difficult to find a flavorful tomato in the supermarket during certain times of the year. The WTP estimate for the modified tomatoes to enhance the nutritional value also shows that there may be a possibility for small premiums. This modification carries a potential premium of approximately 3.25%

TABLE 5
WTP Estimates and Corresponding 95% Confidence Intervals (C.I.)

	Mean WTP Estimate	
WTP	% Premium	Cents per pound
WTP for a tomato modified for enhanced nutritional value	3.2465 (1.5223, 4.7549)	7.4347
WTP for a tomato modified for pesticide reduction	2.1206 (−1.5784, 1.5161)	4.8562
WTP for a tomato modified for increased food shelf life	0.9948 (−0.7043, 2.6953)	2.2781
WTP for a tomato modified for increased profits for farmers	0.0272 (−1.7832, 1.8377)	0.0624
WTP for a tomato modified for enhanced flavor	3.8163 (2.3076, 5.2909)	8.7394

Following Cameron (1991), confidence intervals for the predicted mean WTP estimate can be obtained as: $\text{C.I.}_{.95}[E(\overline{\text{WTP}})] = \overline{X}'\hat{\beta} \pm t_{.025} * \sqrt{\overline{X}\sigma^2(X'X)^{-1}\overline{X}}$.

(or 7.43 cents per pound). This is a timely attribute, as today's consumers are very concerned with nutrition and consuming healthy foods and nutrient supplements.

Additionally, a premium of approximately 4.86 cents per pound (2.12%) can be gained by marketing a tomato as genetically modified for pesticide reduction and 2.28 cents more (about 1%) per pound can be gained for a GM tomato with increased shelf life. Less promising is the premium of 0.5% that consumers are ready to pay for a GM tomato that increases the profits for farmers. This result is currently revealed in the marketplace, where biotechnology products that do not offer any benefit are not generally appreciated by consumers.

CONCLUSIONS

In this paper, we assess consumer response toward GM tomatoes to identify the attribute with the highest level of consumer acceptance. In particular, we consider the following modifications: enhanced nutritional value, pesticide reduction, increased food shelf life, increased profits for farmers, and enhanced flavor. Understanding consumer perceptions toward enhanced biotechnology products is essential, as they are the second generation of GM products.

In this study, a random sample of consumers participated in a mail survey in the western United States, and data were analyzed using a multiple

bounded probit model that fits payment card data. WTP estimates show that consumers are willing to pay the highest premium for the "enhanced flavor" attribute, followed by both the "enhanced nutritional value" and "pesticide reduction" attributes. These results correspond quite well with previous consumer research surveys like the International Food Information Council survey completed in August 2002. In this national survey, consumers stated the top three expected benefits from biotechnology as improved quality/taste/variety (41%), health and nutrition (39%), and reduced chemical and pesticide levels in food production (20%). These findings could be used to improve the average consumer intake of vegetables per household in the United States, which is below the amount recommended by health authorities. Thus, if flavor of vegetables is improved, then the average intake may go up.

In general, the application of these results indicates that emphasizing the direct personal benefits of GM products could prove to be a valuable tool. While WTP values obtained in this study were low and may not show a clear potential for all GM modifications, we can draw conclusions about which beneficial attributes consumers find more important. Our results highlight that attitudinal variables (such as feelings about GM modification) play a statistically significant role in explaining consumer acceptance and WTP for different modifications. The role played by other sociodemographic characteristics is also interesting, particularly those that denote the household income, age, and respondent's education. Our findings show that formal education is not statistically significant and that in one occasion it has a negative effect on consumer acceptance toward a GM-enhanced product. The same is applicable to the age of the respondent. This is somehow offset by the positive role played by the income variable, which is statistically significant for all WTP equations. Further, the variable denoting concerns or perceived risks associated with biotechnology is negative but only statistically significant in one of the regressions. Thus, in spite of the impact of negative media coverage surrounding GM foods, it seems that concerns with this new type of technology are not seriously affecting market opportunities for these new products.

However, it appears that new educational policies may be needed in order for consumers to properly assess the benefits and potential risks associated with biotechnology. Up to now, information regarding GM modification has been confusing, and more educated consumers may show a more cautious behavior in the marketplace.

In previous risk studies, it was shown that women tend to perceive more risk from a hazard than men do and respond in a more cautious manner. Nevertheless, our results indicate that the fact that the respondent is a female

does not decrease the mean WTP for these enhanced GM products. This could show that female value in a positive way these enhanced attributes.

Although the present results are innovative and correspond quite well with other surveys developed with samples similar to the U.S. Census, they offer only a first exploration of consumer response toward different types of genetic modifications. In general, care must be taken in the extrapolation of these results to broader samples, since the sample average age and education are higher than those reported in the U.S. Census. We also need to take into account that the present exercise only analyzes each of the mentioned attributes in an independent way. Consequently, it should be noted that other modeling techniques in which consumers face different products with different attributes at different levels (such as choice-based models or conjoint-type models) would provide interesting insights in terms of trade-offs between the prices that consumers are willing to pay and the different GM applications. However, the primary objective of the current research was the valuation of each of these attributes isolating other potential conflicting effects. For further research, it may be beneficial to learn whether these findings hold for other products, perhaps looking at GM meat or a further-processed product.

ENDNOTES

1. A fiscal year is a 12-month year ending on a date other than December 31. For most individual taxpayers a fiscal year equals a calendar year.

2. The log-linear functional form explored by Cameron and Huppert assumes that WTP is restricted to be positive. In our particular case, since we have bids that equal zero, we are not able to apply the log-linear form.

3. To avoid multicolinearity problems due to the severe correlation between the different stated concerns, the mean of all concerns was used in the empirical analysis.

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APPENDIX

Question Used in the Survey to Elicit WTP for GM Tomato Attributes:

Assuming that there is no known risk (for humans or for the environment), what percentage premium, if any, would you be willing to pay for a tomato that has been modified to benefit you in the following ways (regular price = $2.29 per pound)?

Genetic Modification	Premium Per Pound						
Enhanced nutritional value	None	1%–5%	6%–10%	11%–15%	16%–20%	21%–25%	26%–30%	>30%
Pesticide reduction	None	1%–5%	6%–10%	11%–15%	16%–20%	21%–25%	26%–30%	>30%
Increased food shelf life	None	1%–5%	6%–10%	11%–15%	16%–20%	21%–25%	26%–30%	>30%
Increased profits for farmers	None	1%–5%	6%–10%	11%–15%	16%–20%	21%–25%	26%–30%	>30%
Enhanced flavor	None	1%–5%	6%–10%	11%–15%	16%–20%	21%–25%	26%–30%	>30%

Question Regarding Manipulation of Natural Species:

Where would you place yourself on a scale from 1 to 10 if preserving the natural species at all costs is a 1 and manipulating the natural species in order to get a benefit (in terms of health, well-being, income, etc.) at all costs is a 10? (Please circle just one.)

1 2 3 4 5 6 7 8 9 10

Question Used in the Survey to Elicit Concerns Related to Biotechnology:

How concerned are you about the following *social/ethical*, *health*, and *environmental* issues surrounding genetic modification?

APPENDIX (*Continued*)

	1 = Not at all Concerned	2 = Not Very Concerned	3 = Somewhat Concerned	4 = Very Concerned	5 = Extremely Concerned
Social/Ethical Issue					
1. Patenting life/playing god	1	2	3	4	5
2. Accelerating growth of multinational corporations	1	2	3	4	5
3. May lead to human genetic engineering	1	2	3	4	5
4. Transferring genes between plants and animals	1	2	3	4	5
5. Increase income inequalities between rich and poor countries	1	2	3	4	5
Health Issue					
Allergies	1	2	3	4	5
Increased toxins	1	2	3	4	5
Lower nutrient content in the food	1	2	3	4	5
Unknown consequences to humans	1	2	3	4	5
Environmental Issue					
Effect on nontarget organisms	1	2	3	4	5
Crop-to-crop cross pollination	1	2	3	4	5
Crop-to-weed pollination	1	2	3	4	5
Development of pest resistance to insecticides	1	2	3	4	5