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Consumer Acceptance of Nutritionally Enhanced Genetically Modified Food: Relevance of Gene Transfer Technology

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This study examines consumer's willingness to consume different types of a nutritionally enhanced food product (i.e., breakfast cereal with calcium, omega fatty acids, or anti-oxidants) derived from grains genetically modified using two types of technologies: plant-to-plant gene transfer technology and animal-to-plant gene transfer technology. Findings indicate a majority of the respondents are willing or somewhat willing to consume the three types of nutritionally enhanced genetically modified breakfast cereal, but are less willing if the genetically modified product is derived from animal-to-plant gene transfer technology than from plant-to-plant gene transfer technology. However, the results of the ordered probit models suggest there are groups of consumers who will not approve of the use of either type of gene transfer technology even with the presence of an enhanced nutritional benefit in the product.

Key words: consumer acceptance, gene transfer technology, genetic modification, nutritionally enhanced food products, willingness to consume

Introduction

Farm-level adoption of genetically modified (GM) crops has increased dramatically since their commercial introduction in the United States in the mid-1990s. In 2002, about three-quarters of U.S. soybean acreage and more than a third of corn acreage were planted using GM seeds (U.S. Department of Agriculture, 2002). GM crops have experienced faster adoption rates in the United States than other agricultural innovations such as hybrid corn (Kalaitzandonakes, 1999). Biotechnology has emerged as a technology offering the promise of delivering foods with a wide range of nutritional, economic, and social benefits. The first generation of GM crops was marketed to agricultural producers on the basis of having important input traits such as disease or pest resistance. For instance, bioengineered Bt-corn and cotton and herbicide-resistant Round-Up Ready™ soybeans offered cost-saving opportunities to farmers (Marra, Pardey, and Alston, 2002).

Until recently, scientists and the biotechnology industry operated under the presumption that "sound science" would automatically lead to consumer acceptance of GM products (Krueger, 2001). Contrary to the biotechnology industry's initial optimism, however, GM food products have, so far, faced mixed regulatory and public acceptance

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in the United States and elsewhere (Bredahl, 1999; Gaskell et al., 1999; Hallman et al., 2002). For example, due to consumer concerns, the European Union until recently imposed severe restrictions on the use of GM crops in any segment of its food chain. Even in the United States where GM crops entered the food system without evoking major public resistance, there are signs of increased consumer anxiety about the safety of these crops (Priest, 2000). This misgiving is reflected in recent declines in public support for the use of this technology in food production. As found by surveys conducted by the International Food Information Council (2000), public acceptance of GM foods fell from 78% in 1997 to 59% in 1999.

Although public opposition to food biotechnology is driven primarily by concerns about the safety of GM products for humans and the environment, the use of biotechnology has been criticized also on moral, ethical, and social grounds. The use of biotechnology in plants and animals, especially gene transfer across species, has been opposed on grounds that such practices take us to "realms of God." Since genes are naturally occurring entities which can be discovered (not invented), some argue that granting patents on genetic findings and processes is morally and ethically untenable (Donagy, 2001). The use of genetic technology in agriculture has also raised some important social issues. One such issue is the perceived undesirable social consequences of permanent dependence of farmers on multinational corporations for their "means of production."

Proponents of biotechnology view current consumer resistance to GM foods as being due, in part, to the lack of tangible consumer benefits derived from this technology (Dunahay, 1999; Riley and Hoffman, 1999; Feldman, Morris, and Hoisington, 2000). Consequently, proponents believe the next wave of food biotechnology innovations, which is expected to bring new and improved products with enhanced quality attributes or nutritional benefits desired by consumers, will see much greater public acceptance than the first generation of GM agricultural and food products (Gamble et al., 2002; Schmidt, 2000; Feldman, Morris, and Hoisington, 2000). Recent studies have also found that consumers are less comfortable with genetic modification of animals than with genetic modification of plants (Hallman et al., 2002; Grunert et al., 2000; Hamstra, 1998). However, even within the realm of plant genetic modification, it is also possible that consumers will have different views about use of specific technologies such as the two specifically considered here: (*a*) genetic modification of a plant using another plant's DNA (plant-to-plant technology), and (*b*) genetic modification of a plant using animal DNA (animal-to-plant technology).

The objective of this study is to examine consumers' willingness to consume specific types of a nutritionally enhanced plant-based product (i.e., breakfast cereal) genetically modified using the two types of technologies noted above (plant-to-plant and animal-to-plant). The product of interest is breakfast cereal from GM grains, containing significantly more of one of the following three nutrients (benefits) than non-GM cereal: (*a*) calcium for healthy bones and teeth, (*b*) omega fatty acids which are believed to reduce the risk of heart attack, and (*c*) anti-oxidants which are believed to slow down the aging process.

Ordered probit models are estimated to examine the effects of various factors on consumers' willingness to consume each of these three nutritionally enhanced breakfast cereals derived from either of the two gene transfer technologies considered. Our results indicate that a majority of the respondents are willing to consume the three types of nutritionally enhanced, genetically modified breakfast cereals, but are less willing to do so if the genetically modified product is derived from animal-to-plant gene transfer technology than from plant-to-plant gene transfer technology. However, the results of the ordered probit models do not consistently reflect this preference, suggesting there are groups of consumers who will not approve of the use of either type of gene transfer technology despite the presence of an enhanced nutritional benefit in the product.

The next section discusses previous related studies, followed by a presentation of the conceptual framework used in the analysis, discussion of the survey methodology, development of the empirical model, and results of the analysis. The study ends with a summary overview and concluding remarks.

Previous Literature

Several studies have concluded that consumers are more supportive of genetic modification in plants than in animals (Hallman et al., 2002; Frewer, Howard, and Aaron, 1998). Lusk and Sullivan (2002) found consumer acceptance of GM products improved when genetic modification was achieved by inserting an extra gene from the host plant than when it involved a gene transfer from a different plant.

Findings reported by Moon and Balasubramanian (2001) show U.S. consumer acceptance of GM foods was related to their perceptions of risks and benefits of GM products, as well as their moral and ethical views. Individual attitudes toward corporations, trust in government, and knowledge of science were also found to be important determinants of consumer acceptance. Baker and Burnham (2001) similarly concluded that consumer reception (or lack thereof) of GM foods was related to their cognitive characteristics such as opinions, beliefs, levels of risk aversion, and perceptions of benefits and risks from GM foods. On the other hand, consumer willingness to pay for GM foods was found by Lusk et al. (2001) to be related to their concern about GM food products, but was unrelated to their socioeconomic attributes.

Using survey data from Denmark, Germany, Italy, and the U.K., Bredahl (2001) established that consumer attitudes toward GM foods were driven by their perceptions of risks and benefits of biotechnology. However, respondents did not necessarily distinguish between risks and the benefits of the technology itself. Consumer perceptions of the risks and benefits of GM foods were deeply rooted in their general attitudes toward biotechnology, which in turn influenced consumer intentions to purchase GM foods. Grunert et al. (2000) also reported that consumers in Denmark, Finland, Norway, and Sweden generally associated non-GM foods with safety and good health. GM foods, in contrast, carried negative connotations such as "uncertainty," "unnatural," "diseases/deformities," "loss of species," and "ecological imbalance." Although consumers were more supportive of GM foods which provided specific health benefits, product attributes such as improved taste or functionality did not fully compensate for the negative perceptions about GM foods. In general, the findings of Grunert et al. (2000) revealed that consumers in these countries held a more negative view of animal genetic modification than plant genetic modification.

Burton et al. (2001) modeled willingness to pay for GM-free foods among consumers in the U.K. and found that female consumers and committed buyers of organic foods were willing to pay considerably more for GM-free foods than males and consumers who are not committed to buying organic foods. They also observed lower consumer reception of GM foods when genetic modification involved gene transfer across species. Frewer, Howard, and Aaron (1998) reported similar findings among Italian and British consumers. Our study adds to the existing literature about GM food acceptance by examining the combination of different types of enhanced nutritional benefits and gene transfer technology.

Conceptual Framework

The Lancaster (1966a, b) model provides the natural setting within which consumers' food choices can be analyzed in terms of product attributes. In this model, consumers derive utility (U) from the characteristics or attributes (z) embodied in the products they purchase:

$$U = U(z_1, z_2, \ldots, z_m). \tag{1}$$

Although Lancaster envisioned utility as depending on product attributes only, this framework can be viewed as one where utility depends on product attributes as well as on consumers' personal characteristics.

A random utility, discrete choice model is used in this study to analyze willingness to consume nutritionally enhanced GM foods. Discrete choice models have their roots in the original work of Thurstone (1927) in the context of individual responses to different levels of psychological stimuli. Marschak (1960) viewed utility as the underlying stimulus and applied the utility-maximizing principle to derive the random utility model of discrete choice.

Following the random utility framework, it is assumed a consumer faces a choice between consuming a traditional (T) or a GM (G) variety of the same product. The GM product provides an additional specific nutritional benefit, while the non-GM product provides no such additional benefit. Utilities derived from the GM and the non-GM product varieties are given by U_G and U_T, respectively. However, these utility levels are not directly observable. The observable variables are the product attribute a ($a = T, G$) and a vector of consumer characteristics ($\mathbf{x}$). Specifically, the random utility model assumes that the utility derived by consumer i from the consumption of the product with attribute a ($a = T, G$) can be expressed as:

$$U_{ai} = V_{ai} + \varepsilon_{ai}, \tag{2}$$

where U_{ai} is the unobserved or latent utility level attained by the ith consumer, V_{ai} is the explainable part of the latent utility that depends on the product attribute and the consumer characteristics, and ε_{ai} is the "unexplainable" random component of utility associated with the choice of the product attribute a and consumer i.

Consumer i's choice ordering for the GM food (over the non-GM variety) is assumed to depend on the additional utility derived from the GM product relative to that from the non-GM product, which is denoted here by Z_i. Therefore, Z_i can be specified as:

$$Z_i = (V_{Gi} + \varepsilon_{Gi}) - (V_{Ti} + \varepsilon_{Ti}) = (\varepsilon_{Gi} - \varepsilon_{Ti}) + (V_{Gi} - V_{Ti}). \tag{3}$$

Consumer i will be completely unwilling to consume the GM food if Z_i is not positive, will be neutral to somewhat willing if Z_i is positive but below some threshold value μ, and will be completely willing to consume the GM food if Z_i is greater than μ. Formally, consumer *i*'s choice ordering for the GM food (denoted by Y_i, where $Y = 0$ implies completely unwilling, $Y = 1$ implies neutral to somewhat willing, and $Y = 2$ implies completely willing to consume) is represented by:

$$(4) \qquad \begin{aligned} Y_i &= 0 \quad \text{if } Z_i \leq 0, \\ Y_i &= 1 \quad \text{if } 0 < Z_i \leq \mu, \\ Y_i &= 2 \quad \text{if } Z_i \geq \mu. \end{aligned}$$

Given that a portion of the utility is stochastic in nature, the choice problem (i.e., the choice of the GM food over the non-GM food) can be formulated in probability terms as follows:

$$(5) \qquad \begin{aligned} &\text{Prob}(Y_i = 0 \,|\, \text{Choice Set} = \text{Prob}[Z_i = (\varepsilon_{Gi} - \varepsilon_{Ti}) + (V_{Gi} - V_{Ti}) \leq 0], \\ &\text{Prob}(Y_i = 1 \,|\, \text{Choice Set} = \text{Prob}[0 < Z_i = (\varepsilon_{Gi} - \varepsilon_{Ti}) + (V_{Gi} - V_{Ti}) \leq \mu], \\ &\text{Prob}(Y_i = 2 \,|\, \text{Choice Set} = \text{Prob}[Z_i = (\varepsilon_{Gi} - \varepsilon_{Ti}) + (V_{Gi} - V_{Ti}) > \mu]. \end{aligned}$$

Under the assumption that ε_i ($\varepsilon_i = \varepsilon_{Gi} - \varepsilon_{Ti}$) follows the standard normal distribution, the above probabilistic model yields the well-known ordered-probit model.

For empirical analysis, Z_i is modeled as a function of the *i*th consumer's economic, demographic, and value attributes as follows:

$$(6) \qquad Z_i = \beta'\mathbf{X} + \nu_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \nu_i, \quad i = 1, 2, \ldots, n,$$

where x_{ij} denotes the *j*th attribute of the *i*th respondent, $\beta = (\beta_0, \beta_1, \ldots, \beta_k)$ is the parameter vector to be estimated, and ν is the random error or disturbance term. In this setting, the probabilities of choice for $Y_i = 0$, 1, and 2 are given by:

$$(7) \qquad \begin{aligned} \text{Prob}(Y_i = 0) &= \Phi(-\beta'\mathbf{X}_i), \\ \text{Prob}(Y_i = 1) &= \Phi(\mu - \beta'\mathbf{X}_i) - \Phi(-\beta'\mathbf{X}_i), \\ \text{Prob}(Y_i = 2) &= 1 - \Phi(\mu - \beta'\mathbf{X}_i), \end{aligned}$$

where Φ is the cumulative function of the standard normal distribution. The elements of the β vector and μ can be jointly estimated using the maximum likelihood (ML) procedure. In this framework, the marginal effects of the independent variables on $\text{Prob}(Y_i \mid Y_i = 0, 1, 2)$ are expressed as:

$$(8) \qquad \begin{aligned} \partial\text{Prob}(Y_i = 0)/\partial X_j &= -\phi(-\beta'\mathbf{X})\beta_j, \\ \partial\text{Prob}(Y_i = 1)/\partial X_j &= [\phi(-\beta'\mathbf{X}) - \phi(\mu - \beta'\mathbf{X})]\beta_j, \\ \partial\text{Prob}(Y_i = 2)/\partial X_j &= \phi(\mu - \beta'\mathbf{X})\beta_j, \end{aligned}$$

where ϕ is the density function of the standard normal variable, and X_j is continuous. When X_j is discrete, the marginal effects are obtained by evaluating the $\text{Prob}(Y_i)$ at alternative values of X_j. For the binary predictor variables, the first derivative result does not apply. In order to evaluate the effect of a binary variable, one has to calculate the difference in probabilities when the equation is evaluated at both levels of the binary variable with the other explanatory variables held at their mean values. Hence, the marginal effect of a binary variable is given by:

$$\text{(9)} \qquad \text{Prob}(y = 1|\overline{X}, d = 1) - \text{Prob}(y = 1|\overline{X}, d = 0),$$

where $\overline{X}$ equals the mean of all the other variables, and d is the binary explanatory variable. For example, the probability that a male consumer will accept a plant-based genetically modified cereal providing calcium benefit is given by the difference between the two probabilities—i.e., Prob(*Male* = 1) - Prob(*Female* = 0).

Survey Methodology and Empirical Model

This study uses data from a national telephone survey of adult American consumers. A survey instrument was developed at the Food Policy Institute, Rutgers University, to collect information on public attitudes toward the use of biotechnology in agriculture and their willingness to consume GM foods. Specifically, the survey was designed to gather information on (*a*) public awareness of various issues pertaining to the use of biotechnology in food production, (*b*) public views about various private and public institutions associated with biotechnology research and product development, and (*c*) respondents' willingness to consume GM foods. The survey also sought information on the respondents' socioeconomic and demographic characteristics.

The survey was completed in March-April 2001, by American Opinion Research, a Princeton, New Jersey, based public polling firm. The targeted sample frame for the survey was non-institutional U.S. adult civilians aged 18 years or older. A random proportional probability sample drawn from the more than 97 million telephone households in the United States was purchased from Survey Sampling, Inc. The objective was to obtain a sample size of 1,200 to achieve a sampling error rate of ±3%. Quotas were set to ensure a balanced representation of males and females. In addition, careful measures were taken to make certain the sample drawn was representative of the U.S. population. Once the data were obtained, they were weighted to ensure their representativeness, using race, ethnicity, and education variables as weighting factors.

Each working telephone number was called a maximum of five times, at different times of the week, to contact people who were infrequently at home or were otherwise difficult to reach. A computer-assisted telephone interview (CATI) system was used to complete the survey. While 1,203 respondents completed the survey, another 1,231 individuals either refused to participate or terminated in the middle of the interview. This resulted in a response/cooperation rate of about 50%.[1] To evaluate consumer preferences for selected GM products, the sample was divided into three sub-samples. Out of 1,203 respondents, one-third (400) were asked to indicate their willingness to consume a breakfast cereal derived from a grain that is genetically modified either by plant-to-plant technology or animal-to-plant technology, and that provides one of the three nutritional benefits: calcium, omega fatty acids, and anti-oxidants (giving a total of six different

[1] However, if the response rate is defined as the total number of completed surveys divided by the total number of in-frame sample observations (i.e., the number of household telephone numbers the CATI system attempted to call), the resulting response rate would be about 27%. The difference between this definition of response rate and the one reported in the text is due to the fact that the latter excludes cases such as respondents with language problems, calls picked up by answering machines, and no answers to the telephone calls.

benefit/technology combinations). Another one-third (400) of the respondents were asked to state their willingness to consume hamburger from genetically modified cattle, and members of the remaining one-third of the sample (400) were asked their willingness to consume GM orange juice. For brevity, only the breakfast cereal consumer sample is considered in this paper. In the case of breakfast cereal, a total of 323 (out of 400) completed surveys were used in the empirical analysis due to nonresponses to some of the questions in the survey.

We model willingness to consume breakfast cereal (a plant-based product) from GM grains, which contains significantly more of one of the following three nutrients (benefits) than non-GM cereal: (*a*) calcium for healthy bones and teeth, (*b*) omega fatty acids that are believed to reduce the risk of heart attack, and (*c*) anti-oxidants that are believed to slow down the aging process. Each respondent indicated his/her willingness to consume the GM breakfast cereal if it tasted and cost the same as the regular (i.e., non-GM) product but had the specific benefit of additional calcium, omega fatty acids, or anti-oxidants. The willingness-to-consume question was asked on a 10-point scale.[2] To reduce the number of categories, an ordered dependent variable Y (representing willingness to consume) was defined as follows: respondent i was considered (*a*) "unwilling" to consume ($Y_i = 0$) if his/her willingness to consume was rated between 1 and 4; (*b*) "neutral to somewhat willing" to consume ($Y_i = 1$) if the willingness to consume was rated between 5 and 7; and (*c*) "willing" to consume ($Y_i = 2$) if the willingness to consume was rated between 8 and 10.

The explanatory variables included in the empirical models are: (*a*) demographic variables of age, gender, race, education, knowledge of science, and place of residence (large city or otherwise); (*b*) an economic variable, income; and (*c*) value attributes of socio-political view, attitude toward organic foods, religiosity, views about scientists and biotechnology corporations, and trust and confidence in regulators. These variables were selected based on the existing literature on consumer choice and recent studies on public attitudes toward biotechnology (for a comprehensive review, see Hallman et al., 2002). House et al. (2001) also found that public acceptance of GM foods depends on factors such as trust in scientists and regulators, values, and norms. The definitions and descriptive statistics of the independent variables used in the model are given in table 1.

The following empirical equation is specified to model a consumer's likelihood of choosing the GM food:

$$(10) \quad Z = \beta_0 + \beta_1 MALE + \beta_2 WHITE + \beta_3 YOUNG + \beta_4 MATAGE + \beta_5 LOWEDU \\ + \beta_6 MIDEDU + \beta_7 MIDINC + \beta_8 HIGHINC + \beta_9 WORSHIP\_REG \\ + \beta_{10} WORSHIP\_NO + \beta_{11} LIBERAL + \beta_{12} CONSERV + \beta_{13} CONF\_SC \\ + \beta_{14} SKEP\_CO + \beta_{15} SKEP\_REG + \beta_{16} TRSTGVT + \beta_{17} ORGFV \\ + \beta_{18} CITY + \beta_{19} SUBURB + \beta_{20} GMQUIZ + \nu,$$

[2] The willingness-to-consume question was worded as follows: "I'm going to read you a list of genetically modified foods with a particular health benefit. I'd like to know how much more or less willing you would be to consume these foods as compared with regular foods. Using a scale of 10 to 1, where 10 means *Completely Willing* and 1 means *Completely Unwilling*, and using any number in between, how willing would you be to consume [PRODUCT] if it tasted and cost the same as regular [PRODUCT] but was genetically modified using [SOURCE OF DNA] to have added [BENEFIT]?

Table 1. Descriptive Statistics of Explanatory Variables Used in the Analysis

Variable	Description	Mean	Std. Dev.
MALE	1 = respondent is male; 0 = otherwise	0.47	0.50
YOUNG	1 = age less than 35 years; 0 = otherwise	0.29	0.45
MIDAGE [a]	1 = age is between 35 and 54 years; 0 = otherwise	0.43	0.50
MATAGE	1 = age is 55 years or higher; 0 = otherwise	0.28	0.45
WHITE	1 = respondent is white (Caucasian); 0 = otherwise	0.62	0.49
LOWEDU	1 = education up to high school; 0 = otherwise	0.33	0.47
MIDEDU	1 = 4-year college degree; 0 = otherwise	0.55	0.50
HIGHEDU [a]	1 = more than 4-year college education; 0 = otherwise	0.12	0.33
CONF_SC	1 = has confidence in scientists involved in biotech research and product development; 0 = otherwise	0.41	0.49
SKEP_CO	1 = holds skeptical view about biotech companies; 0 = otherwise	0.67	0.47
SKEP_REG	1 = holds skeptical view about regulators; 0 = otherwise	0.58	0.49
TRSTGVT	1 = trust regulators to do common good; 0 = otherwise	0.50	0.50
ORGFV	1 = respondent believes it is very important that fruits and vegetables be organically grown; 0 = otherwise	0.63	0.48
LOWINC [a]	1 = annual income less than $35,000; 0 = otherwise	0.32	0.47
MIDINC	1 = annual income between $35,000 and $75,000; 0 = otherwise	0.44	0.50
HIGHINC	1 = annual income greater than $75,000; 0 = otherwise	0.24	0.43
WORSHIP_REG	1 = attends church or other house of worship once a week to several times a month; 0 = otherwise	0.46	0.49
WORSHIP_OCC [a]	1 = occasionally attends church or other house of worship; 0 = otherwise	0.30	0.47
WORSHIP_NO	1 = never attends church or other house of worship; 0 = otherwise	0.24	0.43
GMQUIZ	Number of correct responses to 9 science questions	6.07	1.90
CITY	1 = respondent lives in large or medium city area; 0 = otherwise	0.30	0.47
SUBURB	1 = respondent lives in suburban area; 0 = otherwise	0.27	0.45
RURAL [a]	1 = respondent lives in small town or rural area; 0 = otherwise	0.43	0.50
LIBERAL	1 = respondent identifies self as liberal; 0 = otherwise	0.21	0.40
CONSERV	1 = respondent identifies self as conservative; 0 = otherwise	0.28	0.45
CENTRIST [a]	1 = respondent identifies self as in-between; 0 = otherwise	0.51	0.50

[a] The variable is the base or reference group.

where the variables are as defined in table 1. The questions used to derive the *GMQUIZ* variable are presented in table 2.

Six ordered probit models (each corresponding to a particular nutritional benefit and GM technology combination) were estimated to analyze willingness to consume GM foods. The maximum likelihood (ML) estimation procedure was used to obtain the model parameters. The model summary statistics, β-coefficients (along with their t-ratios), and the marginal effects were obtained by using the LIMDEP software package (Econometric Software, Inc., 2002). The standard errors of the marginal effects were estimated by applying a bootstrapping procedure using 500 replications.

Empirical Results

From the statistical analysis, our results indicate that in the case of GM cereal containing added calcium, 41% of the respondents are "willing," 41% are "neutral to somewhat

Table 2. Question Format Used to Derive *GMQUIZ* Variable (number of correct responses from these 9 questions)

	STATEMENT	True	False
1.	There are some bacteria which live on waste water.	[ ]	[ ]
2.	Ordinary tomatoes do not contain genes, while genetically modified tomatoes do.	[ ]	[ ]
3.	If a person eats a genetically modified fruit, their genes could be modified as a result.	[ ]	[ ]
4.	The father's genes determine whether the child is a girl.	[ ]	[ ]
5.	The yeast used to make beer contains living organisms.	[ ]	[ ]
6.	Genetically modified animals are always larger than ordinary animals.	[ ]	[ ]
7.	It is impossible to transfer animal genes to plants.	[ ]	[ ]
8.	Tomatoes genetically modified with genes from catfish would probably taste "fishy."	[ ]	[ ]
9.	Genetically modified foods are created using radiation to create genetic mutations.	[ ]	[ ]

willing," and 18% are "unwilling" to consume when the technology involves gene transfer between plants. When the technology involves gene transfer from animal to plant, those percentages fell to 28% and 38% for the "willing" and the "neutral to somewhat willing" categories, respectively, but increased to 34% for the "unwilling" category (figure 1). In the case of GM cereal with omega fatty acids derived by plant-to-plant technology, 37% of the respondents are "willing," 40% are "neutral to somewhat willing," and 23% are "unwilling" to consume GM cereal. When the technology is animal-to-plant gene transfer, the corresponding values are 31%, 29%, and 40% (figure 2). In the case of the breakfast cereal product with anti-oxidants from grain genetically modified with plant-to-plant technology, 34% of the respondents are "willing," 40% are "neutral to somewhat willing," and 26% are "unwilling" to consume the GM cereal. These values change to 24%, 40%, and 36%, respectively, when the technology is animal-to-plant gene transfer (figure 3). As suggested by these results, respondents are less comfortable with GM foods involving animal-to-plant technology than with GM foods involving plant-to-plant technology.

Given the focus of this study, we report the marginal effects on the probability of being "willing" to consume ($Y = 2$), and consider the statistically significant variables only. To analyze the results, model performance is first established via measures of goodness of fit. In this respect, the statistically significant coefficient for the threshold parameter μ_1, suggests the response categories coded 0, 1, 2 are indeed ordered. Additionally, the χ^2 statistic test for the overall significance of the independent variables is used to reject the null in all six models. Results indicate the regressors chosen were relevant in explaining the likelihood to consume GM breakfast cereal with enhanced nutrients. Second, individual coefficients were subjected to the *t*-test for significance. However, because coefficients from ordered probit models are difficult to interpret, caution must be exercised in using them to make inferences (Greene, 2002). We therefore use the calculated marginal effects to make inferences on how changes in regressors affect the probabilities of particular events.

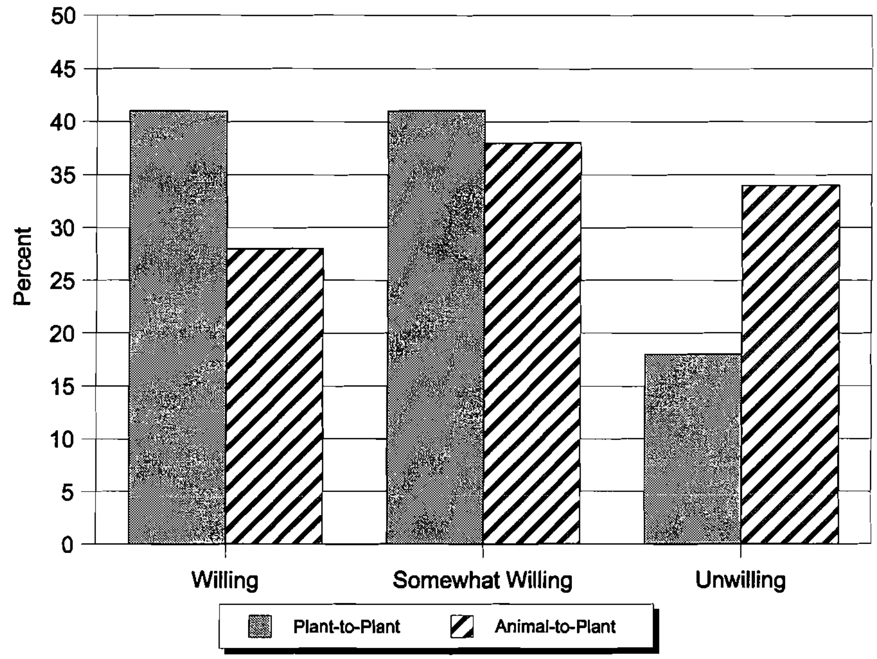

Figure 1. Willingness to consume GM breakfast cereal with calcium by type of gene transfer technology (% of respondents)

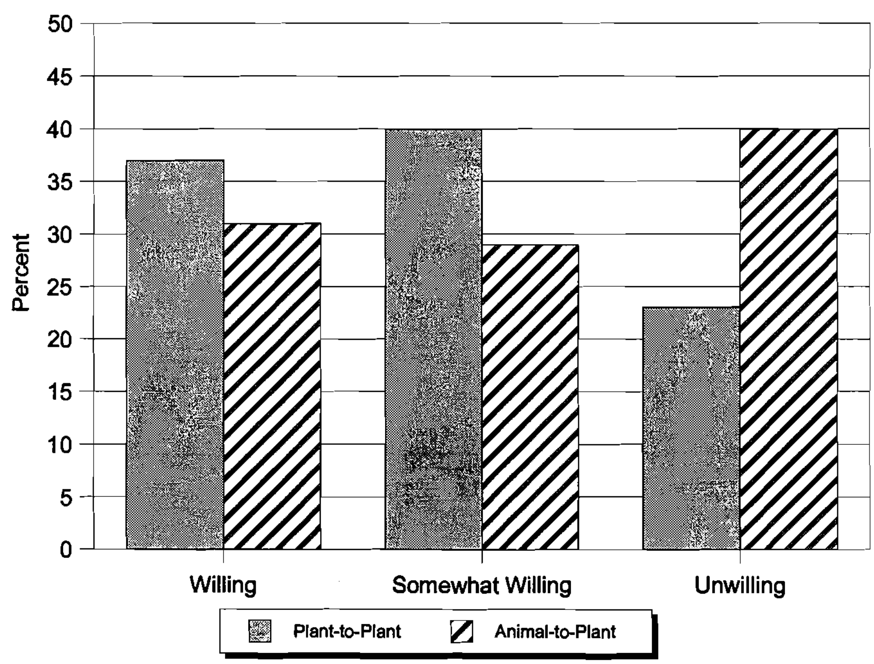

Figure 2. Willingness to consume GM breakfast cereal with omega fatty acids by type of gene transfer technology (% of respondents)

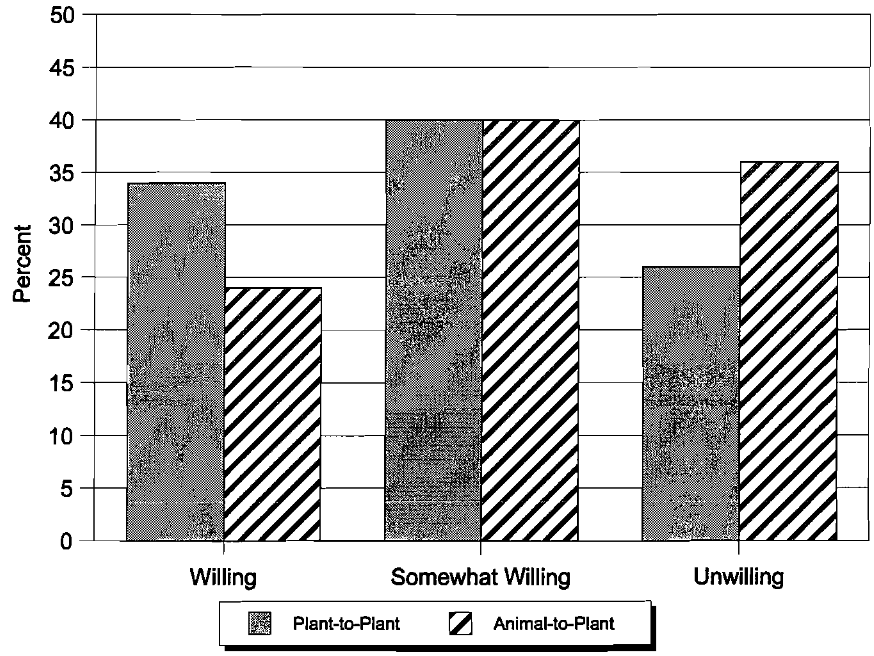

Figure 3. Willingness to consume GM breakfast cereal with anti-oxidants by type of gene transfer technology (% of respondents)

The parameter estimates and the associated *t*-ratios of the models are reported in table 3. The first three columns of table 3 present results pertaining to the plant-to-plant technology case; corresponding results for the animal-to-plant technology case are given in the last three columns. The estimated marginal effects of an independent variable for a given change while holding the other independent variables at their sample means, as well as the model summary statistics, are presented in table 4.

Discussion of the Marginal Effects of Statistically Significant Variables

Results from table 4 indicate males, compared to females, are 13% more likely to consume GM cereal with calcium derived using plant-to-plant technology, and are 9% more likely to consume GM cereal with anti-oxidants derived using animal-to-plant technology than females. Young respondents (age < 35 years) are more likely to consume nutritionally enhanced GM cereal than middle-aged (the base group, aged between 35 and 54) respondents, with probabilities ranging from 14% for GM cereal with omega fatty acids derived using animal-to-plant technology to 21% for GM cereal with calcium derived using animal-to-plant technology. The results also show that older respondents (age 55 and higher) are 9% and 19% less likely to consume a GM cereal derived from animal-to-plant technology, regardless of whether it has been enhanced with omega fatty acids to fight cancer or anti-oxidants to slow down the aging process, compared to middle-aged respondents. These findings mirror those of Grimsrud et al. (2002), whose study of Norwegian consumers found that younger people are more supportive of GM foods.

Caucasians are 11% more likely to consume GM cereal with calcium derived using animal-to-plant technology, and are 12% more likely to consume GM cereal with

Table 3. Estimated Model Coefficients (with *t*-ratios in parentheses)

	Genetic Modification Using Plant DNA			Genetic Modification Using Animal DNA		
Variable	Calcium	Omega	Anti-Oxidant	Calcium	Omega	Anti-Oxidant
Constant	1.169 (2.67)	1.107 (2.56)	1.590 (3.08)	0.130 (0.30)	1.440 (3.02)	1.981 (3.98)
MALE	0.332** (2.30)	0.220 (1.56)	0.010 (0.07)	0.150 (1.06)	-0.026 (-0.18)	0.313 (2.22)
YOUNG	0.404** (2.38)	0.128 (0.77)	0.477** (2.74)	0.603** (3.60)	0.423** (2.50)	0.124 (0.76)
MATAGE	-0.274 (-1.57)	-0.159 (-0.91)	-0.101 (-0.60)	-0.280 (-1.57)	-0.307** (-1.75)	-0.808** (-4.33)
WHITE	0.129 (0.85)	0.126 (0.84)	0.340** (2.34)	0.330** (2.15)	0.081 (0.55)	0.125 (0.85)
LOWEDU	0.430* (1.81)	-0.028 (-0.12)	-0.461* (-1.80)	-0.058 (-0.24)	0.079 (0.33)	-0.760 (-2.92)
MIDEDU	0.149 (0.71)	0.001 (0.01)	-0.550** (-2.33)	-0.522** (-2.50)	-0.196 (-0.91)	-0.805** (-3.44)
MIDINC	-0.126 (-0.72)	0.038 (0.22)	0.200 (1.17)	-0.124 (-0.70)	-0.362** (-2.11)	-0.203 (-1.22)
HIGHINC	-0.159 (-0.81)	-0.015 (-0.08)	-0.046 (-0.24)	-0.403** (-2.03)	-0.754** (-3.82)	-0.491** (-2.54)
CITY	0.072 (0.47)	0.400** (2.66)	-0.584** (-3.70)	0.149 (0.96)	0.130 (0.86)	-0.253 (-1.65)
SUBURB	-0.031 (-0.18)	-0.038 (-0.22)	-0.410** (-2.56)	0.043 (0.25)	-0.479** (-2.80)	-0.383** (-2.29)
GMQUIZ	-0.013 (-0.35)	-0.070** (-1.92)	-0.046 (-1.08)	0.042 (1.14)	0.010 (0.27)	-0.084 (-1.93)
LIBERAL	0.065 (0.39)	0.117 (0.71)	-0.005 (-0.03)	-0.183 (-1.10)	-0.294* (-1.68)	-0.451** (-2.65)
CONSERV	-0.342** (-2.10)	-0.167 (-1.04)	-0.355** (-2.14)	-0.226 (-1.38)	-0.033 (-0.21)	0.061 (0.37)
WORSHIP_REG	-0.154 (-0.97)	-0.052 (-0.33)	-0.098 (-0.63)	-0.036 (-0.23)	0.219 (1.36)	-0.089 (-0.57)
WORSHIP_NO	-1.031** (-5.66)	-0.783** (-4.41)	-0.687** (-3.68)	-0.677** (-3.69)	-0.435** (-2.40)	-0.714 (-3.76)
CONF_SC	0.294** (1.97)	0.196 (1.34)	0.509** (3.49)	0.370** (2.48)	0.289** (1.94)	0.530** (3.59)
SKEP_CO	-0.368** (-2.34)	-0.361** (-2.34)	-0.124 (-0.76)	-0.243 (-1.57)	-0.603** (-3.91)	0.070 (0.44)
SKEP_REG	0.249 (1.68)	0.322** (2.19)	0.220 (1.51)	0.435** (2.91)	0.066 (0.46)	0.236 (1.53)
TRSTGVT	0.231 (1.68)	0.313** (2.30)	0.464** (3.32)	0.288** (2.08)	0.064 (0.45)	0.084 (0.60)
ORGFV	-0.343** (-2.38)	-0.223 (-1.57)	-0.319** (-2.12)	-0.178 (-1.23)	-0.346** (-2.29)	-0.350** (-2.33)
μ_1	1.361** (13.43)	1.216** (13.34)	1.391** (13.96)	0.974** (11.51)	1.205** (13.03)	1.160** (12.50)

Note: Single and double asterisks (*) denote statistical significance of the coefficient at the 0.10 and 0.05 levels, respectively.

Table 4. Marginal Effects of Statistically Significant Independent Variables on the Likelihood of Acceptance of GM Food

	Calcium Benefit		Omega Benefit		Anti-Oxidant Benefit	
Variable	Plant Gene to Plant	Animal Gene to Plant	Plant Gene to Plant	Animal Gene to Plant	Plant Gene to Plant	Animal Gene to Plant
Constant	—	—	—	—	—	—
MALE	0.13	—	—	—	—	0.09
YOUNG	0.16	0.21	—	0.14	0.18	—
MATAGE	—	—	—	-0.09	—	-0.19
WHITE	—	0.11	—	—	0.12	—
LOWEDU	-0.17	—	—	—	-0.16	-0.19
MIDEDU	—	-0.18	—	—	-0.19	-0.23
CONF_SC	0.11	0.13	—	0.09	—	0.15
SKEP_CO	-0.14	—	-0.14	-0.20	—	—
SKEP_REG	—	0.14	0.12	—	—	—
TRSTGVT	—	0.10	0.12	—	0.16	—
ORGFV	-0.13	—	—	-0.11	-0.12	-0.10
MIDINC	—	—	—	-0.11	—	—
HIGHINC	—	-0.13	—	-0.21	—	-0.12
WORSHIP_REG	—	—	—	—	—	—
WORSHIP_NO	-0.34	-0.20	-0.26	-0.13	-0.22	-0.17
GMQUIZ	—	—	0.03	—	—	-0.02
CITY	—	—	0.15	—	-0.20	-0.07
SUBURB	—	—	—	-0.14	-0.14	-0.10
LIBERAL	—	—	—	-0.09	—	-0.12
CONSERV	-0.13	—	—	—	-0.12	—
Model Summary Statistics:						
Log Likelihood Function	-291.27	-308.34	-312.52	-308.92	-297.66	-299.62
Restricted Log Likelihood (all slopes are zero)	-335.65	-352.27	-345.27	-350.27	-342.79	-347.59
χ^2 Statistic of Model Signif. (df = 20)	88.75	87.86	65.51	83.94	90.24	95.95
McFadden's R^2	0.13	0.12	0.10	0.12	0.13	0.14
Model's Prediction Success	52%	53%	52%	50%	53%	56%

anti-oxidants derived using plant-to-plant technology than non-whites. Those respondents with four years of college education or less are less likely to consume GM cereal than those with more than four years of college education. This finding is consistent with those of earlier studies of European consumers as reported by House et al. (2001), and confirmed by Grimsrud et al. (2002) for Norway, and by Boccaletti and Moro (2000) for Italy.

Respondents from cities are 15% more likely to consume GM cereal with omega fatty acids derived using plant-to-plant technology, but are less likely (7% to 20%) to consume GM cereal with anti-oxidants than respondents from rural areas. Boccaletti and Moro (2000) found that more affluent consumers in Italy are more likely to accept GM foods. Those living in suburban areas are also less likely to consume two of the three nutritionally enhanced GM cereal products derived from animal-to-plant technology.

Higher-income respondents are less likely to consume GM cereals, especially when animal-to-plant technology is used. Similarly, respondents who believe it is important for fruits and vegetables to be grown organically are 10% to 13% less likely to consume nutritionally enhanced GM cereals. Interestingly, respondents who never attend church are less likely to consume all six types of GM cereal products than respondents who occasionally attend church. Also, respondents who identify themselves as "conservative" are 12% to 13% less likely to consume GM cereal with calcium and anti-oxidants derived using plant-to-plant technology compared to "centrists," while "liberals" are 9% and 12%, respectively, less likely to consume GM cereal with omega benefit and anti-oxidant benefit derived using animal-to-plant technology compared to "centrists."

As for the attitudinal variables, results suggest respondents who have confidence in scientists involved in biotechnology research and product development are 9% to 15% more likely to consume nutritionally enhanced GM cereals than those without confidence in scientists. Similarly, respondents who trust and have confidence in government regulators are 10% to 16% more likely to consume nutritionally enhanced GM cereals than others. However, respondents who hold a skeptical view of biotechnology companies are 14% to 20% less likely to consume nutritionally enhanced GM cereals than those who trust biotechnology companies. Interestingly, the variable representing respondent's knowledge of science (*GMQUIZ*) is not statistically significant in four of the six models, and the marginal effects of the two statistically significant estimates are relatively small in magnitude.

General Differences in Results Between the Two GM Technologies and Nutritional Benefits

In general, based on the statistically significant marginal effects reported in table 4, some interesting differences are observed between the results of the models for the two types of GM technology analyzed in this study (i.e., animal-to-plant, plant-to-plant). The percentages depicted in figures 1, 2, and 3 show less approval for animal-to-plant technology than for plant-to-plant technology. Indeed, the ordered probit results suggest there are groups of consumers less willing to consume GM foods derived from animal-to-plant technology than GM foods produced using plant-to-plant technology. However, there are also groups of consumers who are less willing to consume GM products derived from plant-to-plant technology. For example, in the anti-oxidant models, the variables *ORGFV*, *WORSHIP_NO*, *CITY*, and *SUBURB* have negative marginal effects in both the plant-to-plant model and animal-to-plant model. Interestingly, the magnitude of these marginal effects, in absolute terms, is greater in the plant-to-plant model than in the animal-to-plant model, implying these groups of consumers have a higher probability of not consuming GM cereal with anti-oxidants derived from plant-to-plant technology than from animal-to-plant technology compared to their counterparts.

There are also some differences in the results between the types of nutritional benefits in the product. Although the majority of respondents are either willing or somewhat willing to consume the types of nutritionally enhanced GM product, the marginal effects from the ordered probit models presented in table 4 also suggest that individual variables have different effects on the likelihood of consuming each type of nutritionally enhanced GM breakfast cereal. For example, gender, ethnicity, and education variables are statistically significant in the calcium and anti-oxidant models, but not in the omega fatty acid models. Skepticism of biotechnology companies and confidence in the ability of regulators are statistically significant in the calcium and omega fatty acid models, but not in the anti-oxidant models.

Summary and Concluding Remarks

Consumer acceptance of GM foods is a key factor that will influence the future of biotechnology in agriculture and the food system. Proponents of biotechnology view the current consumer resistance to GM foods as due, at least in part, to the lack of tangible consumer benefits from this technology. They believe the next wave of food biotechnology innovations, which is expected to bring new and improved products with enhanced nutritional benefits, will see much greater public acceptance. Previous studies have also suggested that consumer acceptance of GM food products would depend on the type of GM technology used.

Our findings do not generally refute these views. A majority of the respondents indicated a willingness to consume the three types of nutritionally enhanced genetically modified breakfast cereal, but are less willing if the genetically modified product is derived from animal-to-plant gene transfer technology than from plant-to-plant gene transfer technology. The results of our ordered probit models suggest there are indeed groups of consumers who are less willing or unwilling to consume products derived from animal-to-plant gene transfer technology. Yet the results also imply there are groups of consumers who have an even higher probability of not consuming GM products derived from plant-to-plant gene transfer technology than GM products derived from animal-to-plant gene transfer technology, despite the presence of an additional nutritional benefit. While these findings are obviously not surprising, they may serve as a reminder to marketers and the food biotechnology industry that there may be no GM food product which can be marketed to everyone, regardless of the additional nutritional benefit the product may provide—a finding which makes the use of market segmentation strategies more compelling.

It is possible that concerns about animal-to-plant gene transfer technology are not quite as high as concerns about animal-to-animal or plant-to-animal genetic modification, as generally implied by findings from previous studies. It is also possible the presence of enhanced nutritional benefit in the product could moderate any negative attitude toward use of animal genes to genetically modify plants or animals. Further research on these issues is clearly warranted. The findings of our study confirm the relevance of not only examining specific types of enhanced nutritional benefits, but also specific types of gene transfer technology used in deriving GM food products.

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