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Public Perceptions of Genetically Engineered Nutraceuticals

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We examine public attitudes and purchase intentions for genetically engineered (GE) nutraceuticals that either offer general health benefits or disease prevention/treatment. A survey that elicited views on genetically modified organisms (GMOs), preferences and purchase intention for GE nutraceuticals and how they are perceived with respect to their conventional and organic counterparts, as well as demographic information, was completed by 1,271 randomly selected students at a Midwestern university. Survey results show that even though the majority of respondents preferred GE nutraceuticals that could prevent or treat diseases to those that offer general health benefits, only a quarter of participants were willing to pay more for these products—an average premium of 20%. Empirical results show that familiarity with genetic modification, shopping habits, and attitudes towards GMOs influence preferences for GE nutraceuticals.

Key words: genetic modification, genetically engineered nutraceuticals, organic food, purchase intentions, willingness to pay.

Introduction

The debate over genetically modified (GM) foods is still going strong two decades after their commercialization in 1996. While public views towards GM foods vary significantly between countries—depending on the country, the proportion of opponents varies between 28% and 82% (Bonny, 2008; Lucht, 2015; Pew Research Center, 2003)—consumer attitudes toward the technology have been influenced by whether it conferred value to producers or consumers. The introduction of first-generation, producer-oriented GM crops that provided agronomic benefits to producers was met with strong consumer opposition (Giannakas & Yiannaka, 2008). In this case, consumers did not perceive a direct benefit from the technology, even though studies show that they too have benefited from the introduction of these crops through lower crop prices (Brookes, Hsiang, Tokgoz, & Elobeid, 2010; Qaim, 2009). When, however, consumers perceive a direct benefit, as in the case of second-generation, consumer-oriented GM products that have enhanced functional properties (e.g., bio-fortified GM foods),[1] they are more accepting of GM food products. De Steur et al. (2015) reviewed more than a dozen studies on willingness to pay (WTP) for bio-fortified GM foods and find that consumers are willing to pay premiums from 20-70% regardless of the targeted crop, micronutrient, or country.

Complementing the benefits of second-generation GM food products, recently developed third-generation GM food products claim to provide health and disease treatment benefits to consumers. *Nutraceuticals*, as such products are called, are foods or parts of foods that provide medicinal or health benefits to consumers, including the prevention and treatment of diseases (Kalra, 2003). Genetically engineered (GE) nutraceuticals include foods associated with increased health benefits and/or disease prevention (second-generation GM food products)—but also foods, plants, and animal products—that could be used to create vaccines and drugs that could treat or cure diseases (third-generation GM products). According to their developers, GE nutraceuticals are designed for the purpose of creating inexpensive alternative pharmaceuticals, fighting disease in developing countries, and improving consumer health through common foods such as fruits and vegetables. Examples of GE nutraceuticals include GE rice that can be used for a cholera vaccine (Murnaghan, 2012), GE bananas that can be used for a Hepatitis B vaccine (American Chemical Society, 2007), and a GE version of the tobacco plant that could be used in a vaccine for the human papillomavirus (HPV) or cervical cancer.

GE nutraceutical products are at different stages of commercialization, with companies operating in both

1. *Examples of bio-fortified crops include vitamin-A-enriched corn, potato, rice, wheat, cassava, and sorghum; folate-enhanced (B9) rice; and mineral-enriched rice (with iron, zinc, and copper).*

the food and pharmaceutical industries better poised at developing them (Rizavi & Folstar, 1999). At present, Astellas Pharma in Japan is at the forefront of conducting clinical trials for a vaccine in rice against diarrheal diseases such as cholera.[2] In the United States, the Food and Drug Administration (FDA) regulates nutraceuticals either as a dietary supplement or a food ingredient depending on how they are marketed by manufacturers (US FDA, 2016). The market for nutraceuticals is growing with an expanding global market valued at $165 billion in 2014 and projected to attain a staggering $278 billion by 2021 (Transparency Market Research, 2018).

Building on a rich literature examining consumer attitudes and WTP for first-generation GM foods (see Chern, Rickertsen, Tsuboi, & Fu, 2003; Hossain & Onyango, 2004; Huffman, Shogren, Rousu, & Tegene, 2003; Lusk et al., 2004), studies on consumer acceptance of functional foods, including second- and third-generation GM food products, find moderate to strong consumer acceptance for these products. Loureiro and Bugbee (2005) used different attributes in GM tomatoes to show that consumers were more accepting of genetic modification when it enhanced the flavor and nutritional value of the vegetable. Colson and Huffman (2011) investigated consumers' attitudes and WTP for GM food products with enhanced properties using *intragenics*, a procedure that implants desirable traits from one food variety to another within the same species. The authors specifically examined fresh vegetables with enhanced vitamin C and antioxidant levels, and found that consumers had a higher WTP for them when the GM vegetables were developed using the intragenic process rather than conventional genetic modification techniques. West, Gendron, Larue, and Lambert (2002) investigated acceptance of foods with functional attributes among consumers in Canada, and also examined preferences for conventional, organic, and GM versions of such foods. Even though respondents were willing to pay as much as a 67% price premium for tomato sauce with an anti-cancer functional attribute, the authors also report that the majority of respondents were averse to the GM versions of the functional foods. In another study about Canadian consumers, Herath, Cranfield, and Henson (2008) used cluster analysis to assess the existing heterogeneity among consumers' acceptance of nutraceuticals and functional foods, although their study did not focus on the GE versions of functional foods. They found that older, more rural, and less educated consumers were most accepting of nutraceuticals and had a higher WTP for them.

The objective of this study is to examine public perceptions of—and purchase intentions for—GE nutraceuticals that either offer general health benefits or disease prevention/treatment. The study also investigates how GE nutraceuticals are perceived with respect to their conventional and organic counterparts that do not offer the same functional properties. Our study is distinct from the literature on consumer attitudes toward nutraceuticals in that it explicitly examines the influence of attitudes toward genetic engineering on perceptions of and attitudes towards GE nutraceuticals. The comparison of GM nutraceuticals to conventional and organic counterparts that do not offer the same functional properties, allows us to examine the following tradeoff—whether those that lack enthusiastic support for genetic modification nevertheless value the enhanced attributes made possible by the technology enough to be willing to purchase the GM nutraceutical. By including third-generation GM products (GE nutraceuticals with functional treatment properties), the study expands upon others that focused only on second-generation GM food products (Colson & Huffman, 2011; Loureiro & Bugbee, 2005).

An online survey that elicited responses related to views on genetic modification, attitudes towards food labeling, preferences for genetically engineered nutraceuticals, and demographic information was developed to achieve study objectives and completed by 1,271 respondents. Two methodological approaches were used to analyze the data: the multinomial logistic regression examined unordered dependent variables pertaining to preferences between GE nutraceuticals versus an organic food substitute while quantile regressions were used to analyze factors that influenced respondents' willingness to pay a premium for GE nutraceuticals that offer prevention or treatment for diseases versus ones that offer general health benefits.

Study results show a strong preference for GE nutraceuticals that offer disease prevention or treatment benefits compared to those that offer only general health benefits, an outcome consistent even among participants opposing genetic modification. However, only a quarter of participants were willing to pay more for these nutraceuticals—an average premium of 20%.

The rest of the article consists of six sections. The next section describes the survey and provides descrip-

2. *Astellas Pharma is collaborating with the University of Tokyo's Institute of Medical Science in developing the rice-based vaccine "MucoRice," which will protect against cholera and E. coli diarrheal diseases (see https://www.astellas.com/en/corporate/news/pdf/160622eg_final.pdf).*

Table 1. Definition of variables and descriptive statistics.

Variable	Description	Mean	Std dev
Shopping habits			
Read articles	1 if articles read or information gathered influence purchasing habits; 0 otherwise	0.66	0.47
Price	Food purchase decisions based on price, scale: 1=low to 5=high	3.98	1.03
Label purchase	Extent to which food labels influence purchase decisions, 1=never to 4=always	2.70	0.71
Opinion of GMOs			
Favor GMOs	Extent to which GM foods are favored or opposed, 1=strongly opposed to 5=strongly favor	3.39	0.91
Label GM	Opinion about labeling food products containing GMOs, 1=strongly disagree to 5=strongly agree	4.02	0.83
Purchase intentions for nutraceuticals			
Prevention nutraceuticals	Willing to purchase GE nutraceuticals if they could prevent illness, 1=highly unwilling to 5=very willing	4.19	0.89
Health nutraceuticals	Willing to purchase GE nutraceuticals if they improve health, 1=highly unwilling to 5=very willing	4.26	0.83
Treatment nutraceuticals	Willing to purchase GE nutraceuticals if they help treat an illness, 1=highly unwilling to 5=very willing	4.39	0.78
Comparatively priced	Likely to purchase GE nutraceuticals if comparatively priced to conventional food, 1=never to 5=highly likely	3.60	0.89
Less expensive	Likely to purchase GE nutraceuticals if less expensive than conventional food, 1=never to 5=highly likely	4.19	0.94
Demographics			
White	1 if subject's ethnicity is white; 0 if nonwhite	0.90	0.31
Age	Age, in years	20.47	4.32
Male	1 if subject is male; 0 otherwise	0.36	0.48

tive statistics, followed by a discussion of consumer attitudes towards GE nutraceuticals. Then we present the empirical models and provide the empirical results as well as concluding remarks.

Data and Descriptive Statistics

A survey instrument was developed to collect information on variables related to participants' shopping habits, attitudes towards genetic modification and food labeling, preferences and purchase intention for GE nutraceuticals with general health, disease prevention, or disease treatment attributes as well as how they are perceived with respect to their conventional and organic counterparts and demographic characteristics. The survey, designed using the *SurveyMonkey* software, was completed online by 1,271 randomly selected students in diverse academic disciplines at the University of Nebraska-Lincoln in the summer of 2009.[3] Information with a brief description of GE nutraceuticals and examples of these products, namely vitamin A enriched Golden Rice™ and rice that has been genetically engineered as an anti-diarrheal medicine for children, were provided in the beginning of the survey (see Appendix).

Table 1 displays descriptive statistics for the variables for all participants. Nearly 66% of respondents reported that articles read or other information gathered influenced their food purchasing habits, a finding which is not particularly surprising for the study's college student sample. For similar reasons, price appeared to be an important consideration in food purchase decisions. Food labels were ranked moderately high as a significant factor that influenced participants' food purchase decisions.

Approval of genetic modification in foods was rated neutral to fairly strong by respondents. Notwithstanding the apparent acceptance of the technology, however, the majority of respondents agreed that foods containing GMOs should be labeled. Participants' intent to pur-

3. *Other studies that have used college students as participants include Lusk et al. (2001); Chern et al. (2003); and Nonis, Hudson, and Hunt (2010).*

Table 2. Prior knowledge/familiarity with GM foods and GE nutraceuticals.

	Mean	Min	Max
Hearing about GM foods for the first time	0.15	0	1
Have listened/read about GM foods	0.75	0	1
Have researched GM foods	0.12	0	1
Hearing about GE nutraceuticals for the first time	0.76	0	1
Have listened/read about GE nutraceuticals	0.20	0	1
Have researched GE nutraceuticals	0.03	0	1

Table 3. Preferences for GE nutraceuticals.

	Proportion willing to purchase		
Nutraceutical offers	**GE nutraceutical**	**Organic food**	**Indifferent**
Disease prevention/ treatment	46%	26%	28%
General health benefits	31%	35%	34%

chase GE nutraceuticals was high overall, but notably so for nutraceuticals genetically engineered to treat diseases.

Regarding demographics, 90% of participants were white, with the average age at approximately 20 years. The majority of respondents were female, accounting for 64% of the sample. As a result of the fairly homogeneous demographic sample, variables with little variability, particularly race, were excluded from further econometric analysis (Lusk, Daniel, Mark, & Lusk, 2001).

Additional responses to survey questions revealed participants' familiarity with genetic modification in foods, and at the same time exposed their unfamiliarity with GE nutraceuticals, as summarized in Table 2. While, for example, 75% of participants had previously read or listened to news stories about GM food products, a similar proportion indicated that the survey was their first exposure to GE nutraceuticals. Further, 20% of participants had either listened to or read news about GE nutraceuticals, while just 3% of participants had explored or researched nutraceuticals.

Attitudes and Purchase Intentions for GE Nutraceuticals

Table 3 summarizes participants' willingness to purchase GE nutraceuticals that offer general health benefits or disease prevention/treatment versus their organic food counterparts that do not offer these benefits when the GE nutraceuticals and the organic versions of these foods are offered for sale at the same price. At 46%, nearly half of participants chose GE nutraceuticals that offer prevention or treatment for a disease over an organic food product. About one-quarter of participants (26%) in this category opted for the organic food alternative, with 28% of respondents indifferent between the two. Preferences for GE nutraceuticals that offer general health benefits are weaker than those that offer disease prevention/treatment. Close to one-third of all participants (31%) chose the GE nutraceuticals claiming to offer general health benefits compared to the 35% who indicated a preference for organic food. About this same proportion of respondents were indifferent between these two products in this category. This result is similar to findings by West et al. (2002) suggesting that consumers ranked nutraceuticals with treatment attributes higher than nutraceuticals without these attributes.

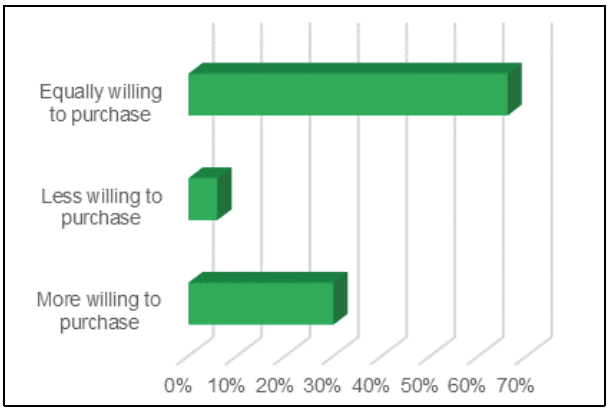

Figure 1. Purchase intentions for GE nutraceutical that offers prevention/treatment versus general health benefits.

To better understand consumer attitudes toward the different functional benefits of nutraceuticals, the study explored respondents' purchase intentions for nutraceuticals genetically engineered to prevent or treat diseases versus GE nutraceuticals that offer general health benefits. As displayed in Figure 1, more than 60% of participants did not necessarily prefer one version over the other, with an equal willingness to purchase GE nutraceuticals with either functional benefit. Approximately 25% of participants reported a greater willingness to purchase GE nutraceuticals with the disease prevention/ treatment attribute, with the remaining 5% of participants less willing to purchase the GE nutraceuticals that can prevent or treat diseases.

In further examination of purchase intentions, a summary of participants' responses concerning willing-

Table 4. Purchase intentions of GE nutraceutical compared to conventional food.

Likely to buy GE nutraceutical if it is	Category	Frequency
More expensive than conventional food	Highly/somewhat likely	17.51%
	Indifferent	17.99%
	Not likely/never	64.50%
Comparatively priced to conventional food	Highly/somewhat likely	57.84%
	Indifferent	32.25%
	Not likely/never	9.90%
Less expensive than conventional food	Highly/somewhat likely	81.93%
	Indifferent	11.33%
	Not likely/never	6.74%

Table 5. Percent premium or discount for GE nutraceuticals with prevention/treatment benefits.

	Obs	Mean % premium	Std dev	Mean % discount	Std dev
More willing to purchase	229	20.03%	15.56%		
Less willing to purchase	32			29.81%	26.71%

ness to purchase GE nutraceuticals that are more expensive, comparatively priced, or less expensive than their conventional food versions is displayed in Table 4. Nearly 18% of participants indicated a willingness to purchase GE nutraceuticals if they were priced higher than conventional food products, and another 18% of participants were indifferent between purchasing the more expensive GE nutraceuticals compared to conventional foods, suggesting a potential niche market for GE nutraceuticals. Approximately 65% of participants were unwilling to purchase the GE nutraceuticals if they are more expensive than their conventional counterparts, clearly indicating that price could play a crucial role in the success of GE nutraceuticals in the marketplace, especially among price-sensitive consumers.

In response to GE nutraceuticals that are comparably priced (or priced lower) to conventional foods more than half of participants indicated a willingness to purchase the GE nutraceuticals. Interestingly, one-third of respondents expressed indifference between purchasing conventional foods and GE nutraceuticals if they were priced the same, suggesting that while this segment of consumers might be open to purchasing GE nutraceuticals, they do not place additional value on their functional benefits.

Finally, we examined purchase intentions by considering premium or discount percentages among participants who were more willing or less willing, respectively, to purchase GE nutraceuticals with the prevention/disease treatment attribute compared to GE nutraceuticals that offer only general health benefits. A summary of the results is reported in Table 5. The average percentage premium among participants who were more willing to purchase GE nutraceuticals with prevention/treatment benefits than GE nutraceuticals with general health benefits was 20.03%, although with some variability (having a standard deviation of approximately 16%). Remarkably, participants who were less willing to purchase GE nutraceuticals with the prevention/treatment attribute requested even higher percentage discounts, at an average of 30%, which was also widely variable, having a standard deviation of 27%.

Preferences for GE Nutraceuticals among Skeptics of Genetic Modification

A key objective of the study is to investigate whether participants opposed to genetic modification in foods would nonetheless value GE nutraceuticals for their health benefits. Table 6 summarizes responses of participants in this category to questions on the survey that elicited purchase intentions for GE nutraceuticals relative to their organic food counterparts. There were 178 participants who were opposed to genetic modification in foods, representing 14% of the sample.

Unlike the nearly 80% who preferred organic food compared to GE nutraceuticals that only offered general health benefits, a lower proportion of participants, 62%, chose organic food when they were presented with nutraceuticals genetically engineered to prevent or treat diseases. Having as many as one-quarter of GM opponents willing to accept foods with genetic engineering indicates the possibility that preferences could shift when consumers perceive a direct benefit from the technology. In addition, the fact that at least 10% of respondents in this category were indifferent between a GE nutraceutical and organic food suggests that opinions

Table 6. Purchase intentions for GE nutraceuticals versus organic food among GM skeptics.

	Obs	Frequency
GE nutraceuticals with health benefits vs organic food		
Genetically engineered nutraceuticals	17	9.55%
Organic food product	142	79.78%
Indifferent between the two	19	10.67%
GE nutraceuticals with disease prevention/treatment benefits vs. organic food		
Genetically engineered nutraceuticals	44	24.86%
Organic food product	110	62.15%
Indifferent between the two	23	12.99%

about genetic modification are malleable and influenced by the perceived benefits that the technology confers.

Empirical Specification

Multinomial Logit Model

The multinomial logit model was utilized in examining choices among K alternatives as a function of respondent characteristics (Hoffman & Duncan, 1988). The alternatives involved a participant's choice for GE nutraceutical (with general health or disease prevention/treatment benefits), an organic food product (offered at the same price as the GE nutraceutical), or indifference between the two products.

As captured by the random utility framework, determinants of an individual's utility can be decomposed into the observable/systematic component and the stochastic component, which is not directly observed (Louviere, Flynn, & Carson, 2010). The random utility function is thus

$$U_{qi} = V_{qi} + \varepsilon_{qi}, \tag{1}$$

where U_{qi} is the unobserved utility when respondent q chooses alternative i, and V_{qi} (= $\boldsymbol{\chi\beta}$) represents the observable component of utility. Individuals are assumed to be utility maximizers. Thus, a respondent will choose alternative i if and only if

$$U_{qi} > U_{qj} \text{ for all } i \neq j, \tag{2}$$

which implies alternative i is chosen if and only if

$$V_{qi} + \varepsilon_{qi} > V_{qj} + \varepsilon_{qj}. \tag{3}$$

Rearranging Equation 3 yields

$$V_{qi} - V_{qj} > \varepsilon_{qj} - \varepsilon_{qi}. \tag{4}$$

The probability that Respondent q chooses Option i is shown in Equation 5, which is also the multinomial logit model (Louviere, Hensher, & Swait, 2000; McFadden, 1973).

$$P_{qi} = \frac{exp(V_{qi})}{\sum_{j=1}^{K} exp(V_{qj})} \tag{5}$$

The reference level, m, was designated as being indifferent between a GE nutraceutical and its organic food counterpart, with the probability given as

$$\text{Prob}\,(m|x) = \frac{1}{1 + \sum_{j=1}^{K} exp(V_{qj})} \tag{6}$$

Quantile Regression

Quantile regression methods were used in analyzing individual characteristics that influenced percentage premiums among respondents who were willing to pay more for GE nutraceuticals that offer prevention/treatment benefits compared to those that offer general health benefits. Quantile regression has some advantages over the ordinary least squares regression (OLS), especially, in allowing relationships between predictor variables to be better portrayed at different quantiles of the conditional distribution of the response variable. Quantile regression can also provide more robust estimators in the presence of outliers (Koenker & Bassett, 1978). While OLS minimizes the sum of squared residuals, quantile regression for the median case minimizes the sum of absolute residuals, i.e., $\sum_i |y_i - x'_i\beta|\, exp(V_{qj})$.

For the more general case involving the q^{th} quantile where $0 < q < 1$, the q^{th} quantile regression estimator, β_q, is obtained as the solution to the minimization problem:

$$\sum_{i:y_i \geq x'_i\beta}^{N} q|y_i - x'_i\beta_q| + \sum_{i:y_i < x'_i\beta}^{N} (1-q)\,|y_i - x'_i\beta_q| \tag{7}$$

The above minimization problem is solved using linear programming methods. In this study, we estimate the regression for two values of q (q = 0.5/median regression, and q = 0.8). The quantile regression model and the variables used are specified in Equation 8:

$$\begin{aligned} Premium = {} & \beta_0 + \beta_1 articles\_read + \beta_2 price \\ & + \beta_5 label\_GM + \beta_6 prevention\_nutra \\ & + \beta_5 label\_GM + \beta_6 prevention\_nutra \\ & + \beta_7 health\_nutra + \beta_8 treatment\_nutra \\ & + \beta_9 comparatively\_priced \\ & + \beta_{10} less\_expensive + \beta_{11} male + \beta_{12} age + \varepsilon \end{aligned} \quad (8)$$

The dependent variable, *Premium*, represents the percentage premium respondents are willing to pay for GE nutraceuticals that offer prevention/treatment benefits compared to GE nutraceuticals with general health benefits.

Results and Discussion

Multinomial Logit Results—GE Nutraceuticals with General Health Benefits

The first set of results for the multinomial logit model are displayed in Table 7. These are results related to respondents' purchase intentions for a GE nutraceutical with general health benefits versus an organic food product if both were offered for sale at the same price, relative to being indifferent between the two.

Beginning with prior knowledge/familiarity, participants who were being exposed to genetic modification for the first time were two times (1/0.497) less likely to choose organic food relative to being indifferent between the two food types. In contrast, participants who were hearing about GE nutraceuticals for the first time were 1.62 times more likely to choose the organic food product. While organic food is the more familiar food type between the two, it is also likely that participants did not significantly value the general health benefits' attribute of the GE nutraceutical.

Concerning shopping habits, subjects whose food choices were influenced by previous articles or information read were also likely to choose the GE nutraceutical or organic food, but more so the latter in this case. However, when price was an essential determinant in food choices, participants were more willing to purchase the GE nutraceutical, with a 16% increase in their odds for each level up the scale. Individuals whose food purchase decisions were influenced by food labels were 1.73 times more likely to purchase the organic food product. These findings illuminate consumer characteristics that may influence their views about genetic modification (particularly when a non-GM option is present) and how such sentiments could in turn influence preferences for GE nutraceuticals.

Table 7. Multinomial logit results: GE nutraceuticals with general health benefits versus organic food.

	GE nutraceuticals		Organic food	
Parameter	**Estimate**	**Odds ratio**	**Estimate**	**Odds ratio**
Intercept	-7.564*** (1.088)		-0.526 (0.991)	
Prior knowledge/familiarity				
First-time GM foods	0.157 (0.210)	1.170	-0.699*** (0.236)	0.497
First-time GE nutraceuticals	0.211 (0.183)	1.235	0.484** (0.193)	1.622
Shopping habits				
Articles read	0.312* (0.161)	1.366	0.568*** (0.174)	1.764
Price	0.147** (0.075)	1.158	0.070 (0.079)	1.072
Food labels	0.040 (0.122)	1.040	0.550*** (0.128)	1.733
Opinion of GMOs				
Favor GMOs	0.538*** (0.110)	1.713	-0.545*** (0.113)	0.580
Label GMOs	-0.051 (0.095)	0.950	0.485*** (0.112)	1.623
Purchase intentions for nutraceuticals				
Prevention nutraceuticals	0.338* (0.182)	1.402	-0.245 (0.162)	0.783
Health nutraceuticals	-0.097 (0.194)	0.907	-0.050 (0.177)	0.952
Treatment nutraceuticals	-0.035 (0.172)	0.965	-0.089 (0.154)	0.914
Comparatively priced	0.320*** (0.118)	1.377	-0.104 (0.122)	0.901
Less expensive	0.388*** (0.128)	1.474	-0.187 (0.116)	0.829
Demographics				
Male	0.025 (0.161)	1.025	-0.249 (0.173)	0.780
Age	0.035 (0.023)	1.036	0.031 (0.022)	1.031

, **, * Estimated coefficient is significant at the 10%, 5%, and 1% significance levels, respectively.*
Standard errors are given in parentheses.
Note: Reference category: Indifferent between the two products (nutraceuticals & organic product)

Participants who viewed GM foods more favorably understandably had a higher odds of choosing the GE nutraceutical, and they were less likely to choose the organic food product—specifically 1.72 times (1/0.580) less likely for each level up the scale. This segment of consumers would be undoubtedly very critical to the

future success of GE nutraceuticals. Advocates of GM food labeling had a 62% increased odds of choosing the organic food product. Even though consumer attitudes towards genetic modification in food may have changed since its introduction, early studies on attitudes towards GM foods—such as Huffman et al. (2003)—reported that consumers placed a 14% discount on GM-labeled food compared to their conventional versions. Evidently, some participants who hold strong views about labeling GMOs were also reluctant to choose the GE nutraceutical when an organic food option was present.

Three variables related to purchase intentions for GE nutraceuticals were statistically significant. Significant at the 10% level, participants who were more willing to purchase GE nutraceuticals that served as prophylaxis (*Prevention nutraceuticals*) were also more likely to choose the GE nutraceutical that offers general health benefits. This aligns with previous findings that consumers are more accepting of genetic modification in foods when it enhances the nutritional or health value (Loureiro & Bugbee, 2005; Onyango & Govindasamy, 2005).

In keeping with survey results showing price sensitivity, respondents who were more likely to purchase GE nutraceuticals if they were cheaper or comparatively priced to conventional foods recorded greater odds of choosing the GE nutraceutical. While this is not surprising for the college student sample used in this study, Herath et al. (2008) found that older Canadian consumers rather than younger ones were willing to pay a higher price for nutraceuticals.

Multinomial Logit Results—Nutraceuticals with Disease Treatment Benefit

The second set of multinomial logit results reported in Table 8 examines purchase intent between a GE nutraceutical that offers disease prevention/treatment benefits and its organic food version sold at the same price, relative to being indifferent between the two.

Similar to findings displayed in Table 7, shopping habits that influenced preferences for the GE nutraceutical or its organic food counterpart (relative to being indifferent) were *Articles Read* and *Food Labels*. Respondents whose food purchase decisions were influenced by prior articles read were also more likely to purchase the GE nutraceuticals with the prevention/treatment attributes, but the odds were even greater for preferring an organic food product. Where product labels were a key factor in food decisions, participants were 1.74 times more likely to choose the organic food, relative to being indifferent.

There was little substantial difference in preferences between GE nutraceuticals with the general health benefits and those engineered to prevent or treat diseases, with respect to opinions of GMOs. Participants in support of genetic modification were also more likely to

Table 8. Multinomial logit results: GE nutraceuticals with disease prevention/treatment attribute vs. organic food.

	GE nutraceuticals		Organic food	
Parameter	**Estimate**	**Odds ratio**	**Estimate**	**Odds ratio**
Intercept	-6.611*** (0.996)		-0.923 (1.054)	
Prior knowledge/familiarity				
First time GM foods	-0.093 (0.206)	0.911	-0.290 (0.253)	0.748
First time GE nutraceuticals	-0.075 (0.176)	0.928	0.326 (0.220)	1.386
Shopping habits				
Articles read	0.391** (0.155)	1.479	0.607*** (0.195)	1.835
Price	-0.003 (0.072)	0.997	0.020 (0.089)	1.020
Food labels	0.123 (0.118)	1.131	0.554*** (0.142)	1.740
Opinion of GMOs				
Favor GMOs	0.337*** (0.102)	1.400	-0.220* (0.122)	0.803
Label GMOs	0.154 (0.095)	1.167	0.483*** (0.123)	1.622
Purchase intentions for nutraceuticals				
Prevention nutraceuticals	0.013 (0.164)	1.013	-0.164 (0.177)	0.849
Health nutraceuticals	-0.218 (0.182)	0.804	-0.192 (0.192)	0.826
Treatment nutraceuticals	0.562*** (0.163)	1.755	-0.344** (0.163)	0.709
Comparatively priced	0.390*** (0.114)	1.477	-0.073 (0.137)	0.930
Less expensive	0.315*** (0.113)	1.370	-0.027 (0.128)	0.973
Demographics				
Male	0.235 (0.157)	1.265	0.094 (0.194)	1.098
Age	0.014 (0.021)	1.014	0.024 (0.021)	1.024

, **, * Estimated coefficient is significant at the 10%, 5%, and 1% significance levels, respectively. Standard errors are given in parentheses. Note: Reference category: Indifferent between the two products (nutraceuticals & organic product)*

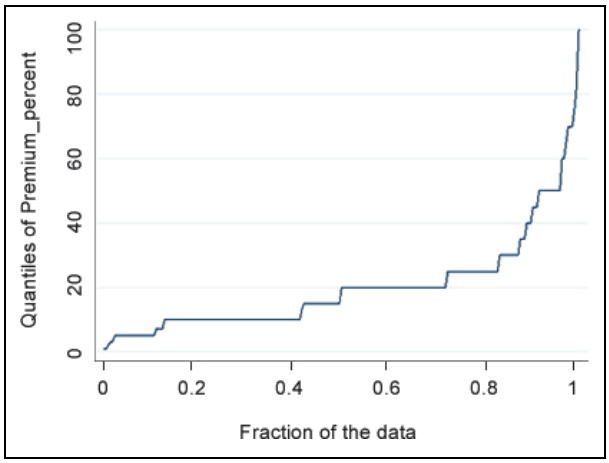

Figure 2. Distribution of percentage premiums for GE nutraceuticals with disease prevention/treatment benefits.

choose the GE nutraceutical that offered prevention or treatment benefits, whereas those who wanted GMOs labeled had greater odds of choosing the organic food version.

The more willing a respondent was to purchasing nutraceuticals engineered to treat diseases, the more likely they were to choose the GE nutraceuticals, relative to being indifferent. Despite its disease prevention/treatment benefit, participants showed a similar price sensitivity to these nutraceuticals as to those that offered general health benefits; those who valued nutraceuticals similarly priced or less expensive than conventional foods were more likely to choose the GE nutraceutical with the disease prevention/treatment attribute.

Quantile Regression Results

The distribution of WTP premiums is examined prior to considering results from the quantile regression. These are the price premiums in percentages given by respondents willing to pay more for GE nutraceuticals capable of preventing or treating diseases, relative to those that offer general health benefits. As displayed in Figure 2, the distribution shows a gradual increase until it crosses the 85th percentile. The median premium is approximately 18%, rising slightly to 25% at the 80th percentile. As the bulk of the distribution shows, the majority of respondents who were willing to pay more did not appear to weigh the benefits of GE nutraceuticals with the prevention/treatment attributes significantly higher than the version with general health benefits to command very high premiums. Though the maximum WTP premium is 100%, only a fraction of premiums submitted for GE nutraceuticals with the prevention/treatment benefits exceeded 25%.

Table 9. Quantile regression results for premium percentages for GE nutraceuticals with prevention/treatment attributes (*N* = 219).

	q50	q80
Parameter	**Estimate**	**Estimate**
Intercept	16.466	49.117**
	(18.031)	(24.956)
Prior knowledge/familiarity		
First time GM foods	5.450**	7.105
	(2.557)	(8.689)
First time GE nutraceuticals	-3.654	-1.522
	(2.320)	(3.969)
Shopping habits		
Articles read	-4.423*	-11.982**
	(2.653)	(5.147)
Price	-0.262	-5.398*
	(1.283	(2.929)
Food labels	-0.089	-0.939
	(1.794)	(2.446)
Opinions of GM		
Favor GM	-0.702	-3.332
	(1.311)	(2.189)
Label GM	0.879	1.509
	(1.606)	(2.310)
Purchase intentions for nutraceuticals		
Prevention nutraceuticals	-0.017	1.925
	(1.827)	(3.518)
Health nutraceuticals	-3.448	-4.492
	(2.509)	(4.825)
Treatment nutraceuticals	3.389	5.085
	(2.557)	(4.115)
Comparatively priced	0.980	0.870
	(1.173)	(2.183)
Less expensive	-3.273**	-2.759
	(1.352)	(2.410)
Demographics		
Male	-4.078*	-6.137*
	(2.185)	(3.221)
Age	0.880	0.765
	(0.671)	(0.827)

, **, * Estimated coefficient is significant at the 10%, 5%, and 1% significance levels, respectively.*
Standard errors are given in parentheses.

Estimates of the quantile regression analysis are shown in Table 9, for both the median and the 80th percentile regressions. Starting with participants' prior knowledge/familiarity, those exposed to genetic modification for the first time were willing to pay 5.5% more for the GE nutraceuticals with the disease prevention/

treatment attributes than nutraceuticals that offer general health benefits. This is significant at the 5% level for the median regression and indicates a higher WTP interest in GM products with enhanced functional attributes (Loureiro & Bugbee, 2005). Concerning participants' shopping habits, *Articles Read* and *Price* were the statistically significant variables, even though the latter was not significant in the median regression and was significant at the 10% level in the 80th percentile regression. The more likely a respondent's food purchasing decision was influenced by previous articles read, the less willing they were to pay a high price premium, varying at different points along the distribution. At the 80th percentile, price premiums for participants in this category were 12% less for the GE nutraceuticals with prevention or disease treatment attributes—and 4.4% less at the median—for each level on the scale. Although such respondents are also expected to be well informed about food choices, price sensitivity appears prominent in shaping preferences for nutraceuticals among young consumers (Herath et al., 2008). As would be expected, the price premiums for GE nutraceuticals with the prevention/treatment attributes were approximately 5% lower at the 80th percentile among participants for whom price was a significant determinant in food buying decisions for each level up the scale.

None of the two variables in the opinions of GM segment was statistically significant. In further support of participants' price sensitivity, those who were more likely to purchase a GE nutraceutical when it was priced lower than their conventional food equivalent also recorded lower percentage premiums for each level on the scale. Regarding participants' demographics, males were less likely to pay more for GE nutraceuticals than females. The median regression shows that males would pay 4% less in premiums for the GE nutraceuticals with prevention/disease treatment attributes and an even lower premium at the 80th percentile.

Conclusions

This study examined perceptions of and purchase intentions towards GE nutraceuticals and determined whether young consumers were willing to purchase GE nutraceuticals when offered for sale at the same price with other food types, specifically conventional and organic food products that do not offer similar health or disease prevention/treatment benefits. These objectives were accomplished using a survey instrument that targeted college students, thus, reflecting the views of a younger consumer segment.

Our results show stronger preference for GE nutraceuticals with disease prevention or treatment attributes than GE nutraceuticals that only offer general health benefits. Faced with a choice between a GE nutraceutical with disease prevention or treatment benefits and its organic counterpart, nearly half of all respondents preferred the GE nutraceutical. For these consumers, GE nutraceuticals modified to prevent or treat diseases were viewed as being vertically differentiated to their organic counterparts; if offered at the same price, the GE nutraceutical would be chosen. This finding is consistent even among opponents of GMOs; among this group, one-quarter were open to GE nutraceuticals that prevented or treated diseases, preferring this over organic food. However, when the GE nutraceutical provided general health benefits, only about one-third of all respondents were willing to purchase it when an organic food option was present.

Even though our results suggest a promising market potential for GE nutraceuticals, the fact that about 76% of respondents indicated hearing about GE nutraceuticals for the first time during the survey implies that manufacturers of GE nutraceuticals could play an important role in informing consumers about the beneficial attributes of these products.

Despite the significant acceptance of GE nutraceuticals with the prevention/treatment attributes, results show that the way they will be priced with respect to their conventional and organic counterparts is critical for their market success. The average price premium for GE nutraceuticals that prevent or treat diseases was 20% over GE nutraceuticals that only offer general health benefits. In addition, only about 18% of study participants indicated a willingness to purchase GE nutraceuticals if they were more expensive than conventional food. Although consistent with previous studies such as De Steur et al. (2015) who found that consumers were willing to pay premiums between 20-70% for bio-fortified foods, our results reflect the regional, college student sample used, who are not main income earners. Notwithstanding our study limitations, our findings show acceptance of biotechnology applications that offer direct benefits to consumers.

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Appendix

Description of GE Nutraceuticals as Given in the Survey

> "Genetically modified (GM) foods are food items that have had their DNA changed through genetic engineering" (Wikipedia, 2009). Genetically modified food products in the Midwest are commonly associated with crops such as corn genetically engineered to be pest resistant.

The term "nutraceuticals," a combination of the words "nutrition" and "pharmaceutical," was quoted in 1989 by Dr. Stephen DeFelice, who defined them as foods or parts of foods that provided medicinal or health benefits to consumers, including the prevention and treatment of diseases (Kalra, 2003). Genetically engineered nutraceuticals are nutraceuticals that have been genetically engineered. An example of a genetically engineered nutraceutical that could offer general health benefits and/or prevent a disease is Golden Rice™, a vitamin-A-enriched rice that could be used by those suffering from vitamin A and other micronutrient deficiencies (Welch & Graham, 2004). An example of a genetically engineered nutraceutical that could treat a disease is rice, WHICH IS genetically engineered to produce anti-diarrhea medicine for children (Haarlander, 2007).