Does Physical Activity Influence Consumer Acceptance of Gene Edited Food?

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Abstract: Consumer acceptance of new and emerging food production technologies is tied to their understanding of costs and benefits of the product. Advances in bioengineering not only provide direct nutritional benefits to the consumer, but also environmental benefits that improve sustainability. Improved consumer understanding of the benefits of innovative bioengineered food products can aid in the adoption process. We track participants’ physical activity level to determine whether this trait impacts willingness to pay for bioengineered foods. Additionally, we determine whether consumers are willing to pay a premium for gene edited food relative to genetically modified food. The results indicate that there is no link between physical activity and willingness to pay for genetically edited food. Additional results suggest that there is a premium among Asian and other respondents but not by gender.

Keywords: consumer valuation; food; gene editing; genetically modified; physical activity

1. Introduction

Technological advances in food production are becoming increasingly complex. Direct understanding of the potential benefits of new technologies and/or food products is difficult for consumers to understand, resulting in slower adoption of products despite widespread adoption by producers [1]. Consumer acceptance of food production technologies and purchasing habits are tied to their understanding of the cost-benefit of the specific technology. Stability of concerns over time, as indicated in [1] regarding new food production technologies, may illustrate how consumers transfer information from one item to a range of similar products [2]. The more information available about the product’s attributes, the easier it is for the consumer to make an informed decision regarding the product’s benefits relative to the costs. In addition to the costs and benefits to the individual, there may be additional costs and benefits to the welfare of others (including corporate social responsibility and fair trade) and to the environment (i.e., sustainable) through reductions in pesticide applications and water usage.

Consumer knowledge of genetic modification (GM) technology in food and agriculture is limited. The Pew Research Center [3] found that less than 30% of U.S. citizens claim to have been widely exposed to information about GM foods. Nearly one-fifth of respondents to that study had never heard anything about GM. Improved understanding of genomes has allowed science to transition from genetically modifying a food product to genetically editing (GE), which are both forms of bioengineering technologies. Genetically modified organisms (GMOs) involve alteration of the organism’s genetic information through the introduction of genetic information from another organism. GE utilizes enzymes and/or proteins to edit the genome of an organism to acquire the desired trait, which is more precise than earlier forms of GM technologies [4]. Consumers do recognize the difference...
in breeding technologies, but they are generally more interested in how the technology directly affects them rather than why the technology is used [1]. With science continuing to outpace consumers’ knowledge regarding the use and application of food production technologies related to genomes, the nature of consumer resistance is multi-dimensional [5].

There is abundant literature evaluating consumer willingness to pay (WTP) for a wide range of products [4,6–13]. Previous studies have focused on specific food attributes available to the consumer in order to improve the understanding of consumer valuation for new food products. These studies all indicate the benefits of purchasing the item for the consumer, whose knowledge of the underlying food production systems varies. Our study builds on the existing literature by clearly conveying the potential benefits of the consumption of GE food items. We add to the existing literature by evaluating whether there is a price premium for different types of GE food technologies that clearly convey the benefit to the consumer relative to GM technology. A novel approach is added to differentiate this study from prior work, as we track the physical activity levels of respondents as a proxy for measuring healthy behavior over a two-day period to determine its impact on willingness to pay for food items that are produced with differing levels of food technology. Tracking actual physical activity levels provides a greater understanding of preferences for bioengineered food items to consumers who reveal themselves to be more (or less) health-conscious based on their actual physical activity levels. The rest of the paper continues with a discussion of existing literature, followed by the research methods, results, and finally the implications of our research and conclusions.

2. Background

Bioengineering (which includes GMO and GE technologies) increases the productive capacity of land already devoted to agricultural production and it also expands the land used in instances where drought-tolerant crop varieties allow for production in areas previously considered unsuitable for cultivation. The positive impacts of these bioengineering technologies (GM and GE) to agricultural production mentioned in previous literature include increased yield and quality of GM maize [14], improved drought tolerance [15], more precise breeding techniques [13,16], reduced chemical pesticide and fungicide use and increased farmer profits [10,17,18], and reductions in pesticide-related poisonings and increased food security [19]. Although the seed varieties are more expensive for farmers, the increased food supply leads to lower food costs for consumers. The direct benefits of bioengineering technologies may not be directly understood or immediately captured by consumers, which may result in skepticism over the benefit that accrues for an individual consumer. McComas et al. [20] stated that the presence of who bears the risk in terms of food safety with the benefits being aggregated to others can result in lowered support for genetic modification. In this regard, Shew et al. [10] found that when clear environmental benefits of a food item are clearly presented to consumers, bioengineered items receive a price premium relative to bioengineered items that do not include these benefits.

Consumer acceptance of new technologies is affected by factors including, but not limited to, morals, culture, and health concerns [21], as well as perceived naturalness [11]. Consumer knowledge of bioengineering (whether GE or GMO methods) is limited by a lack of consumer education, with favorable attitudes toward science and new technology offsetting the stigma often associated with novel foods [13]. Lusk et al. [1] concluded that consumers acknowledge distinctions between different crop breeding technologies such as GM or GE. However, the final results of the breeding technology were of more interest to the consumers than the breeding process itself. Consumers admitted “they were not particularly knowledgeable about such issues” [1], which allows for the use of pejorative terms to still resonate with consumers [21]. This also provides power to retailers to limit the ability of consumers to have access to processed products [18], which reduces the accrual of environmental benefits to society.

Despite commercial production of GM crops occurring since 1995 [19], consumers hold a preconception that there are still food safety risks associated with GM food [1]. According
to the American Association for the Advancement of Science (AAAS), “crop improvement by the modern molecular techniques of biotechnology is safe [22]”. Introduction of gene-editing technologies has caused concern about the possible regulatory implications for the final consumer, as they are not subject to the same regulatory process as food products that are genetically modified in the United States.

Approximately 90% of Americans want mandatory labeling for genetically modified foods [23]. Support for such labeling requirements contributed to the passage of the National Bioengineered Food Disclosure Law in 2016. This may reflect the consumer not being aware that the benefits that accrue are to the individual’s health or the environment, as suggested by Lusk et al. [1]. The U.S. Department of Agriculture’s Agricultural Marketing Service (USDA AMS) lists 13 bioengineered foods produced in the U.S.: alfalfa, apples, canola, corn (field/sweet, but not popcorn), cotton, eggplant, papaya, pineapple, potato, salmon, soybean, squash, and sugar beet [24]. The Non-GMO Project claims 43,623 products and counting as being GMO-free even though there is no genetically engineered crop produced that is an input into the final product, which includes items such as chocolate and cat litter [25]. Wunderlich and Gatto [26] pointed out that the use of the Non-GMO Project label indicates that the product contains less than 0.9% GMO ingredients, which can lead the consumer to feeling an unnecessary bias against GMO production.

The new gene-editing technology has not been extensively studied in terms of consumer acceptance. Gene editing cuts DNA sequences at specified locations, using “site-specific nucleases” [27]. From this point, the genetic code can be left as is, or a clipped strand from another genetic code can be inserted. Transcription activator-like effector nucleases (TALEN) are a form of gene editing that creates site-specific mutations, allowing for greater precision in the selection of (economic) desirable characteristics. TALEN proteins cut the desired DNA at the target site of the DNA strand, and these TALEN strands then complete the DNA sequence [27]. This precision allows for the desired result without affecting other parts of the genome. Potato varieties produced using the TALEN method have shown no presence of the TALEN sequence used to produce the genetic modification in subsequent generations, making it a transgene-free approach. The result of this method of genetic modification is that it does not introduce different genes into the genetic code [28]. The TALEN process for gene editing may have different consumer acceptance than other forms of genetic modification technologies. This is the central question of the paper.

Previous research indicates there are heterogeneous effects of consumer acceptance and willingness to pay for different types of bioengineering food technology [4,13,29–31]. To our knowledge, the relationship between acceptance and willingness to pay for bioengineered foods and physical activity has not been measured in previous studies. Prior research has measured healthy behavior through self-reported consumer attitudes toward food and its nutritional content and/or taste [32,33], which is not a holistic view of healthy behavior. As Dimmock et al. [34] stated, exercise may influence other health behaviors. There are at least three processes in play (cognitive, impulsive cognitive, and physiological), according to [34], and use of physical activity trackers helps reveal how these behaviors influence demand for bioengineered foods. In addition, it is known that consumers often struggle with balancing short- and long-term goals as it relates to health [35–37]. There are two hypotheses we seek to evaluate in this paper.

**Hypothesis 1 (H1).** There is no difference in the willingness to pay for GE and GMO potatoes.

**Hypothesis 2 (H2).** Healthy behavior, measured using physical activity as a proxy, affects the willingness to pay for GE technologies.

### 3. Materials and Methods

Our interest in the use of bioengineering focuses on the willingness to pay (WTP) in regard to potatoes, given their prevalence in the diet of many U.S. citizens. According to the U.S. Department of Agriculture’s Economic Research Service, potatoes have the largest...
per capita availability of any item classified as a vegetable [38]. The Innate 1.0 potato is what our study focuses on, as this specific potato is known for reduced bruising and acrylamide content when heated, which is a known carcinogen [18,39]. The first-generation Innate potato entered fresh and chip markets in 2015, after being approved by the USDA in 2014 [18]. A reduction in bruising of potatoes can lead to reduced food waste and in turn improve sustainability due to decreased input usage. The initial version of the Innate potato focused on desirable consumer traits (reduced bruising and acrylamide), with subsequent versions focusing on late blight resistance and cold storage capability [18,40,41]. Simplot [41] estimated significant reductions in water and carbon dioxide emissions from the reduced bruising and non-browning trait. Halterman et al. [18] estimated the sustainability benefits of potatoes with reduced black spots (bruising) of 145,000 fewer hectares of reduced pesticide applications and a decrease of 55 billion liters of water used. Although we are studying consumer acceptance in regard to potatoes, the results are relevant in terms of the comparison of GE and GM technology, as it is the source of the variation in our study.

Participants in a consumer valuation experiment were recruited by a university laboratory dedicated to human experiments. A recruitment email was sent to faculty, staff, and students inviting them to participate in a three-consecutive-day research study. For each of the three days, participants came to the lab, signed in, and signed a consent form. On the first day, participants received instructions about the research and each participant was issued a pedometer watch to measure their physical activity. The issued pedometer was zip-tied to the participant’s wrist and was verified to be at zero steps and powered on. Participants were compensated for each day they participated in the research trial, with steps recorded on the second and third day of the research project.

On the second day, returning participants had their previous day’s activity levels recorded and the pedometer was reset to zero before the participants left the session. Participants then responded to a questionnaire with one of three randomly assigned information treatments. The information treatments were provided to analyze how three different information sources impacted participants’ WTP. The information treatments were (a) based on information available from the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) that focused on the reduced carcinogens of a GE potato (included in Appendix A); (b) information from the Pew Research Center [3], WHO, and FAO and highlighting the longer storage life of the potato, which impacts the producer and potato industry (included in Appendix B); and (c) no information control. The information treatments are provided in the appendices.

After the participants read the information treatment described above, they were then given a consumer valuation question for two types of bioengineered potatoes and a cash voucher option. A hypothetical sample choice question is shown in Figure 1. Option A was a genetically edited potato with a longer storage life and reduced carcinogens when fried, Option B was a GMO potato with reduced black spots with a cash voucher, and Option C was a voucher that was randomly valued at USD 0.05 to USD 0.10 higher than the coupon in Option B. The base value for the voucher in Option B ranged from USD 0.10 to USD 1.00 and was drawn from a uniform random distribution, as was the increased value in Option C. The presence of Option C allowed for consumers who did not consume potatoes or any type of bioengineered foods to express their true preferences. The consumer choice task with varying prices allowed for the inference of valuation for genetically edited potatoes, given the randomized prices seen by participants. On the third and final day, participants answered demographic and attitudinal questions and had their physical activity (number of steps) from the previous day recorded. Participants were allowed to keep the pedometer and received additional monetary compensation for participation on all three days.
Figure 1. Hypothetical choice example.

Attitudinal questions included in the exit questionnaire gauged participants’ prior knowledge regarding bioengineered foods. The first two questions asked the individual how informed they were about GMO/GE foods prior to taking the survey. Answer options included “informed”, “somewhat informed”, or “not informed at all”. Participants were then asked how strongly they agreed or disagreed with the following statements. Individuals were asked, after reading the information provided in this survey, whether they were more likely to buy a GMO (GE) food. The next question was whether gene-edited foods and genetically modified foods should be treated the same. The last attitudinal question was whether genetically engineered foods are an effective way of feeding a growing global population. The answer options to each of these four questions were “strongly agree”, “agree”, “neutral”, “disagree”, or “strongly disagree”.

4. Results

This study was carried out over a 15-day period between September 2019 and February 2020 in a mid-size city in the Southwestern United States. Each respondent visited the lab daily for three consecutive days. The study was repeated weekly with a different cohort for a period of five weeks. Of the initial 313 participants, a total of 282 individuals completed the hypothetical choice task (this terminology is consistent with Lusk et al. [8] (p. 1017)) and the required three visits to the laboratory. Prices were allowed to randomly vary between individuals to infer valuation. The demographic data of the participants are presented in Table 1. The median age of 22 in this study is below the median U.S. age of 38.2 [42] and can be explained by the study occurring on a college campus. Non-students were a minority of our sample, with the majority being undergraduate students. The average number of steps completed each day by the participants in our sample was significantly higher than the average person, who completes somewhere between 3000 and 4000 steps a day [43]. Given that our sample was recruited from a university population, we controlled for demographic differences in our regressions.

Participants were asked on an exit questionnaire how informed they were about GMO and GE foods, whether gene-edited and genetically modified foods should be treated the same, and whether genetically engineered foods are an effective way of feeding a growing global population. Results from these questions are provided in Table 2. Respondents felt somewhat informed about GMOs (1.14/2), but not informed about GE foods (0.75/2). After reading the survey, participants were neutral about whether they were more likely to buy GMO (3.13/5) or GE food (3.16/5). Participants’ attitudes were neutral on whether gene-edited and genetically modified foods should be treated the same (3.07/5). Respondents tended to agree that genetically engineered foods are an effective way of feeding a growing global population (3.90/5). Only on the last question of whether GE foods are an effective way of feeding a growing global population was there no difference among means based on which information treatment the participant received. The question on how informed participants were before the survey regarding GE foods found statistically significant means between the three information treatments. For the remaining questions, a t-test of two means assuming equal variance found that there were differences between those
who received either the WHO or industry information treatment and those who received no information.

Table 1. Demographic data.

| Variable          | Mean  | Standard Deviation |
|-------------------|-------|--------------------|
| Age               | 24.14 | 7.26               |
| Female            | 59.14%| 0.49               |
| Household size    | 2.52  | 1.56               |
| White             | 27.56%| 0.45               |
| Hispanic          | 18.73%| 0.39               |
| Black             | 6.01% | 0.24               |
| Asian             | 41.70%| 0.49               |
| Other             | 6.01% | 0.22               |
| Income < USD 45,000| 42.70%| 0.49               |
| Income USD 45,000–USD 49,000 | 4.27% | 0.20               |
| Income USD 50,000–USD 59,000 | 7.47% | 0.26               |
| Income > USD 60,000 | 33.81%| 0.47               |
| No Income Given   | 11.74%| 0.32               |
| Undergraduate Student | 58.72%| 0.49               |
| Graduate Student  | 34.88%| 0.48               |
| Non-Student       | 6.41% | 0.24               |
| Day Two Steps     | 15,164.95 | 5947.75          |
| Day Three Steps   | 14,543.36 | 5795.06           |
| Total Steps       | 29,261.93 | 10,302.72         |

Note: Respondents who selected more than one race were included in the "Other" category.

Table 2. Prior information about genetically edited and modified foods.

| Question                                                                 | Mean | Standard Deviation |
|--------------------------------------------------------------------------|------|--------------------|
| Before taking this survey, how informed were you about GMO foods? \(^1\) | 1.14 \(^{a,b}\) | 0.70               |
| Before taking this survey, how informed were you about GE foods? \(^1\)  | 0.75 \(^{a,c,d}\) | 0.71               |
| After reading the information provided in this survey, I am more likely to buy a GMO food. \(^2\) | 3.13 \(^{b,c}\) | 0.908              |
| After reading the information provided in this survey, I am more likely to buy a GE food. \(^2\) | 3.16 \(^{a,b}\) | 0.831              |
| Gene-edited foods and genetically modified foods should be treated the same. \(^2\) | 3.07 \(^{a,b}\) | 1.02               |

\(^1\) Options were “informed” (2), “somewhat informed” (1), and “not informed at all” (0). \(^2\) Options were “strongly agree” (5), “agree” (4), “neutral” (3), “disagree” (2), and “strongly disagree” (1). \(^a\) The mean was significantly different between the WHO and no-information treatments at the 1% significance level. \(^b\) The mean was significantly different between the industry and no-information treatments at the 1% significance level. \(^c\) The mean was significantly different between the WHO and industry treatments at the 5% significance level. \(^d\) The mean was significantly different between the industry and no-information treatments at the 5% significance level.

Additional analysis was conducted for the correlation of attitudinal questions regarding genetic engineering technologies. Using Spearman’s correlation coefficient, there was a high level of correlation between the questions that asked whether the individual was more likely to buy a GMO/GE food after reading the survey (coefficient of 0.604, \(p < 0.01\)). There was not a significant difference between the means of these two questions based on all participants’ responses. The correlation between these two questions was the strongest of all the attitudinal questions, but all the correlation coefficients were highly significant \((p < 0.01)\). For all of the attitudinal questions presented in Table 2, there were no significant differences in means based on the level of physical activity (i.e., whether someone was above or below the median step count).

A mixed logit model \([44–46]\) was estimated to obtain the price premiums or discounts for genetically edited potatoes relative to genetically modified potatoes. Premiums (discounts) present reflect the utility for person \(n\) given by the choice of alternative \(j\) given choice situation \(t\), which can be specified as:

\[
U_{njt} = \beta' x_{njt} + \epsilon_{njt}
\]
where \( x_{njt} \) is a vector of observed attributes, \( \beta'_{n} \) is the vector of structural parameters that vary over all observations, and \( \epsilon_{njt} \) is a random term that represents the unobservable portion of utility, further described in [45]. The model was estimated in willingness-to-pay space in STATA (StataCorp LLC, College Station, Texas, USA) using the mixlogitwtp command, allowing for the utility coefficients to vary across individuals as the marginal WTP values entered the utility function. Utility derived by each individual \( n \) in choosing alternative \( j \) at choice \( t \) can be expressed as:

\[
U_{njt} = -\sigma_n(p_{njt} + wt_{n}'x_{njt} + \epsilon_{njt})
\]

where \( p_{njt} \) is price, \( wt_{n} \) is a vector of WTP for each nonprice attribute, and \( \sigma_n \) is a random scalar [46,47]. That is, the magnitude of the estimates is the actual marginal willingness to pay for the variables of interest. The benefit of estimating the model in willingness-to-pay space is that in WTP space models, the utility is reparametrized so that the attribute coefficients can be directly interpreted as marginal WTPs. In WTP space models, the price/scale coefficient can be treated as random in order to overcome the confounding distributional assumptions of price and scale parameters (standard deviation of the unobserved utility) that usually occur in preference space due to the specification of the price as a fixed parameter [48,49].

The dependent variable was the choice of the three options (GE potato, GMO potato and cash, or cash coupon) with the option of a genetically edited potato specified as a random variable in the models. Price was included in the model per Equation (2). In additional models where the GE potato option was interacted with variables of interest (e.g., physical activity), we were able to include variables that would otherwise be invariant for the individual. The option of a genetically edited potato was specified as a random variable in our models. Since the model was estimated in WTP space, the parameter estimates were interpreted as the marginal price premium/discount for each independent variable. Please see [45–49] for the mathematical notation and estimation procedures of the mixed logit model in WTP space using STATA’s \textit{mixlogitwtp} command.

Log likelihood tests failed to reject differences in willingness to pay for genetically edited potatoes relative to genetically modified potatoes based on their randomly assigned information treatment. Given that the experiments were conducted in a three-week period in September and October 2019 and an additional two-week period in February 2020, additional log likelihood tests failed to reject differences in willingness to pay for genetically edited potatoes relative to genetically modified potatoes based on when respondents participated in the research. Results are shown in Table 3 (WTP Estimate 1 column) and indicate a USD 0.54 premium for GE potatoes relative to GMO potatoes. Preference heterogeneity was present in the results, meaning that the main effect of USD 0.54 had preference variation among the participants. We then interacted thousands of steps taken with the GE potato option from the choice task and estimated the premium for GE potatoes relative to GMO potatoes when controlling for physical activity levels. There was a USD 0.52 premium for GE potatoes relative to GMO potatoes, as shown in the rightmost column of Table 3 (WTP Estimate 2 column). Physical activity level was not a significant factor in explaining a respondent’s WTP. Estimated results were robust to whether the second or third day’s physical activity level was included in the model. The results for physical activity are consistent with the initial model that was estimated and shown in Table 3. Preference heterogeneity was also present when controlling for physical activity levels. Based on these results, we conclude that the physical activity level of the participants did not seem to be a strong predictor of acceptability of gene-edited food. This result points to a potentially more general preference and a lack of correlation between GE food and physical activity. Consistent with Asioli and Grasso [50], this result indicates that a premium exists among consumers when food products reduce food loss (longer shelf life in the GE potato relative to the reduced black spots in the GMO potato). The benefits of increased quality and/or decreased safety concerns present in the GE potato provide additional support to [51,52] in that these factors are more important than sustainability.
Table 3. Willingness-to-pay estimates for genetically edited potatoes and physical activity relative to genetically modified potatoes.

| Variable                                               | WTP Estimate 1 | WTP Estimate 2 |
|--------------------------------------------------------|----------------|----------------|
| Mean Parameter for Genetically Edited Potatoes         | 0.545 ***      | 0.529 ***      |
| Price/Scale                                            | -0.001         | 0.052          |
| Thousands of Steps on Day 2*Genetically Edited Potatoes| 0.000           | 0.000          |
| Standard Deviation Parameter for Genetically Edited Potatoes | 0.172 **      | 0.170 *        |
| Standard Deviation Parameter for Price                 | 1.638          | 1.551          |
| N                                                      | 282            | 282            |
| Log Likelihood Value                                   | -300.663       | -300.655       |

Note: * This column does not include an interaction effect with the number of steps taken; three asterisks (***), two asterisks (**), and one asterisk (*) denote significance at the 1%, 5%, and 10% level, respectively.

An additional model including sociodemographic controls and selected interaction effects with the number of steps taken in thousands was estimated and is shown in Table 4. Attitudinal questions were not included in this model due to the possibility of introducing endogeneity. Consistent with the results in Table 3, there was a premium (USD 0.635) for gene-edited potatoes when controlling for sociodemographic and its interaction with the number of steps taken (in thousands). The number of steps taken did not impact results for the model presented in Table 4. There was a premium for gene-edited potatoes among Hispanics and other races. Graduate students discounted the gene-edited potato relative to undergraduate students (USD −0.340) with no significant difference found between non-students and undergraduate students. These results are consistent with [7] in that demographics are not a significant influence on WTP. There was no preference heterogeneity when accounting for sociodemographic controls and their interaction with the number of steps taken in thousands.

Table 4. Willingness-to-pay estimates for genetically edited potatoes relative to genetically modified potatoes for selected demographic and interaction variables.

| Variable                          | Mean   | Standard Error |
|-----------------------------------|--------|----------------|
| Female                            | 0.384  | 0.301          |
| Female*Steps                      | -0.033 | 0.022          |
| Hispanic                          | 1.346 ** | 0.649        |
| Black                             | -0.179 | 0.018          |
| Asian                             | -0.163 | 0.114          |
| Other                             | 0.500 *** | 0.113      |
| Income <USD 45,000                | 0.294  | 0.270          |
| Income<USD 45,000*Steps           | 0.000  | 0.018          |
| Income USD 45,000–USD 49,000      | 0.226  | 0.917          |
| Income USD 45,000–USD 49,000*Steps| -0.003 | 0.072          |
| Income USD 50,000–USD 59,000      | -0.140 | 0.782          |
| Income USD 50,000–USD 59,000*Steps| -0.002 | 0.050          |
| No Income Given                   | -0.962 | 0.607          |
| No Income Given*Steps             | 0.072 * | 0.040        |
| Graduate Student                  | -0.340 *** | 0.081     |
| Nonstudent                        | -0.128 | 0.121          |
| Thousands of Steps on Day 2*Genetically Edited Potatoes | -0.007 | 0.016         |
| Mean Parameter for Genetically Edited Potatoes         | 0.635 *** | 0.229        |
| Price/Scale                        | 0.026  | 0.663          |
| Standard Deviation Parameter for Genetically Edited Potatoes | 0.001  | 0.021         |
Table 4. Cont.

| Variable                                      | Mean  | Standard Error |
|-----------------------------------------------|-------|----------------|
| Standard Deviation Parameter for Price        | 2.801 | 1.171          |
| N                                             |       | 274            |
| Log Likelihood Value                          | −273.623 |              |

Note: Three asterisks (***), two asterisks (**), and one asterisk (*) denote significance at the 1%, 5%, and 10% level, respectively. All demographic variables as well as the physical activity level were interacted with the option of a GE potato to avoid inclusion of invariant variables in our model.

5. Discussion

Our results indicate that there is a premium for gene-edited relative to genetically modified food products. The premium difference between gene-edited and genetically modified was consistent when accounting only for the physical activity level and sociodemographic controls with interaction of the physical activity level. Physical activity level, which served a proxy for healthy behaviors, was not a significant factor in our results. This suggests that consumers’ preferences for bioengineered foods are not impacted by their physical activity level. Other healthy behaviors and attitudes may influence the decision more than their physical activity level. It is possible that the lack of significance of physical activity may reflect that we only looked at one food item and not a basket of food items that are bioengineered.

Differences in information treatments provided to participants did not impact their valuation of products described in our research. There were significant differences in attitudinal questions posed based on which information treatment was randomly provided. Our results may suggest that consumers like the availability of benefits associated with gene-edited foods but would prefer not to purchase those food products.

As this technology is still relatively new, consumers may not be reacting to its availability, as it is not prevalent in the products they routinely purchase. As stated in [18], the ability of food retailers and processors to limit consumer access to food products may limit consumer adoption when available and limit producers’ desire to use crop varieties with clear environmental benefits. More information on the benefits provided to consumers along with decreased novelty may result in dynamic changes in how people accept and value GE products. This can change the consumer’s assessment of the cost–benefit ratio not only in the immediate purchase decision but also over the long term when decreased carcinogens can improve the consumer’s health status.

6. Conclusions

Advances in food production are rapidly changing and consumers may not be able to keep up with the direct benefits from the purchase of products. Improved understanding of genomes allows for new technologies that can offer direct benefits to consumers now and in the long term. Skepticism of the benefits of bioengineering could impact consumer acceptance as this technology becomes more prevalent in food production as improved understanding of genomes occurs.

Our results are consistent with prior studies that demonstrated that consumers are more accepting of biotechnology with clear health benefits to the consumer [4,20,52,53]. We agree with Muringai et al. [4] in that these benefits may aid in consumer acceptance. The results are consistent with existing literature that consumers are more accepting of GE products (cisgenic) than GMO products (transgenic) [4,11,13,30]. “Naturalness” may be a desirable trait by consumers [11], but this is not always the same as being an agricultural production method that is environmentally friendly.

This paper also contributes to the existing literature by finding that there is not a link between physical activity and willingness to pay for certain types of biotechnology used in food production. Research should continue to discover the links between physical activity and willingness to pay for different food products and bioengineering technologies, but this
is an important first step. Future research should analyze whether there is a premium for genetically edited potatoes (or food products in general) relative to conventional potatoes in a more representative sample of U.S. consumers.

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**Informed Consent Statement:** Informed consent was obtained from all subjected involved in the study.

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**Conflicts of Interest:** The authors declare no conflict of interest.

**Appendix A**

**Information Treatment 1: WHO/FAO**

- Genetically modified organisms (GMOs) are a biotechnology that is produced by altering the DNA of an organism. Recent scientific advancements have allowed the alteration of this DNA to focus specifically on certain genes. Gene editing is one of the recent advancements, and alters DNA of an organism by adding or removing specific pieces of genetic code.
- One example of gene editing is the TALEN process, which allows an enzyme to cut the DNA in a specific place. The accuracy of this process allows for the desired attribute of the product to be passed on to the final consumer.
- Recent concerns about long-term safety and consequences of gene-edited food, including the TALEN process, have resulted in consumers being concerned about the health risks this new technology could cause. According to the World Health Organization (WHO), “Specific systems have been set up for the rigorous evaluation of GM organisms and food relative to both human health and the environment.” These systems have been set up to ensure proper testing of all GM crops that could one day be consumed by the final consumer.
- An example of a TALEN product is a potato that has a lower count of carcinogens when fried. This potato has been deemed safe by both the WHO and the United Nations Food and Agriculture Organization (FAO). Therefore, this potato is safe for consumer consumption, and the potato has the added benefit of having a reduced number of carcinogens.
Appendix B

Information Treatment 2: Industry

- Genetically modified organisms (GMOs) are produced by altering the DNA of an organism. Recent scientific advancements have allowed the alteration of this DNA to focus specifically on certain genes.
- The agriculture industry is rapidly adopting GMOs due to beneficial attributes GMOs provide to the farmers and food processors. For example, the CRISPR process is a form of gene editing that allows an enzyme to cut the DNA in a specific place. This allows for an exact benefit to be procured for the industry's benefit.
- The World Health Organization claims that GM organisms are evaluated to ensure health for both the consumer and the environment that could be affected by the GM biotechnology. According to the PEW Research Center, 43% of Americans trust scientific information regarding biotechnology in food.
- An example of a CRISPR product is a potato that can be stored longer, which reduces perishability concerns that the industry might have about produce. This potato has been deemed safe by both the WHO and the Food and Agriculture Organization (FAO). This potato is safe for consumption, according to two different agencies, and aids the industry by reducing costs.

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