



Article Consumer Acceptance of Genome-Edited Foods in Japan

Ryoma Shigi and Yuna Seo *

Department of Industrial and Systems Engineering, Graduate School of Science and Technology, Tokyo University of Science, Noda 278-8510, Chiba, Japan; 7422520@ed.tus.ac.jp * Correspondence: yuna.s@rs.tus.ac.jp; Tel.: +81-4-7124-1501

Abstract: Genome-edited (GE) food is recently being introduced into the market with the promise of efficient food production and food waste reduction. Genetic editing aims to accelerate genetic progress by replacing the germ cell lineage of commercial breeding animals with cells derived from genetically elite lines. At the present early stage of the GE food market in Japan, this study investigated consumer acceptance of GE foods and constructed a GE foods acceptance model. This model illustrated that awareness of GE technology is essential for the stimulation of consumer acceptance, which is mediated by information credibility and the perceived usefulness of GE foods. It suggests that Japanese consumers may demand more information about how GE foods are produced and what their benefits are. Further research on effective food technology education and on communication about GE foods is needed.

Keywords: genome-edited food; consumer acceptance; perceived usefulness; information credibility

1. Introduction

Genome editing (GE) can be used to accelerate the rate of genetic progress by enabling the replacement of the germ cell lineage of commercial breeding animals with cells derived from genetically elite lines [1]. In 2019, GE technologies have been applied to more than 50 different plants [2]. Given its powerful applications in crop improvement, GE technology has made significant advancements in recent times [3]. Not only does GE technology revolutionize plant biology, but it also offers solutions to challenges pertaining to plant architecture, food security, nutrient content, environmental adaptation, disease resistance, and the production of plant-based materials. [4]. Thus, GE is an efficient method to produce foods and reduce food waste [5].

GE foods have gained global attention with regard to the need to address environmental and social risks. The British Parliament released a POSTnote on genome editing clarifying that the government is proposing that genome-edited crop plants are exempted from GMO regulations, provided that the genetic changes could occur naturally or via existing conventional breeding techniques [6]. Nigeria has authorized guidelines on gene editing through the National Biosafety Management Agency (NBMA) [7]. Indonesia drafted a regulation on CRISPR-based GE and other GE techniques in early 2021 [8].

Japan is a step ahead of the others and has introduced GE food permits. Moreover, safety assessment and notification are not mandatory for GE foods in Japan [9]. This superaging country is facing a declining birthrate along with its aging population. Accordingly, the agriculture sector is short of labor and the area that is farmland continues to decrease. It is feared that agriculture skills will not be inherited, and the production base will become even more fragile. Thus, it is necessary to strengthen the production base and improve production efficiency [10]. Under these circumstances, GE foods have been envisioned as new risk-tolerant foods.

The acceptance of innovative and transformative technologies by consumers plays a crucial role in their implementation and in building the capacity to transform food systems. Given that Japanese consumers are conservative and wary of embracing new trends, they



Citation: Shigi, R.; Seo, Y. Consumer Acceptance of Genome-Edited Foods in Japan. *Sustainability* **2023**, *15*, 9662. https://doi.org/10.3390/su15129662

Academic Editor: Roberto Mancinelli

Received: 26 April 2023 Revised: 15 June 2023 Accepted: 15 June 2023 Published: 16 June 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). have also been cautious about novel foods [11,12]. Several studies have investigated factors affecting acceptance among Japanese consumers. Motoki et al. suggested that contexts (such as being in a pub or restaurant) would influence the willingness to try novel foods [13]. Others have suggested that scientific interest would be an important factor for alternative proteins [14,15]. However, there is limited empirical research exploring the impact of consumer attitudes and their acceptance of GE foods. GE foods are among the least recognized new foods and are possibly often confused with genetically modified organism (GMO) foods [16]. Accordingly, we assumed that information would be an important factor to influence consumers' acceptance. We then designed hypotheses of influential factors of GE food acceptance in light of consumer perceptions of new technologies and benefits, and developed a consumer acceptance model for GE foods.

2. Literature Review and Hypotheses

We explored the literature of novel foods and their acceptance regarding awareness of food technology, information credibility, and usefulness. Before stating the hypotheses developed below, the main concepts are introduced as follows.

Awareness of food technology refers to perceived levels of GE technology knowledge. Information credibility refers to how much consumers are concerned about the reliability of the information source. Usefulness refers to consumers' perceived interest in the contribution of GE foods to their nutritional issues, health promotion, and the sustainability of food industry sectors.

2.1. Effect of Technology Awareness and Information Credibility on Willingness to Buy

The food industry is undergoing major changes in response to changing social needs caused by environmental issues and population growth. In this regard, as farmers and manufacturers develop new technologies to respond to a rapidly changing environment, consumers face new foods, and they cannot adequately determine if these affect their health and promise to be beneficial. Previously, concern over the health and environmental burden resulting from the use of agricultural chemicals led to the revival of organic food, which does not involve editing the product as it is, but only replaces the chemicals that are detrimental for the environment with better ways that have a less adverse impact or none. Organic food successfully found a place in the market, with outstanding performances in both production and sales [17]. Meanwhile, social needs such as health promotion, high yields, lower environmental burden, animal welfare, and so on have stimulated technological innovation to develop foods in entirely different ways from the conventional amendments in cultivation or livestock raising. For example, GMO technology was developed in the 1980s and nine GMO crops are on the market at present. It is one of the plant biotechnology applications by which a plant is created by duplicating some of the preferred genes or genetic material of a plant or organism and inserting it into another plant or invalidating or transferring its existing genes. Although the safety of GMO foods is strictly controlled by governments [18], many consumers remain skeptical, which has led to discussions worldwide and suggests the need for effective communication strategies [19–22].

Many surveys have tried to determine the effective factors to communicate about new foods that consumers face. In particular, several studies have suggested that information seemingly plays an important role in moderating consumers' attitudes [23,24]. Specially designed GMO labelling with information about its health-related and social usefulness enhanced consumers' willingness to pay. Moreover, certified labelling reassures consumers to buy GMO foods [25], suggesting that information credibility is critical. These trends are also found for other novel foods. Global demand for meat is forecasted to increase rapidly as the world population grows [26], further raising concerns about the increasing environmental burden while maintaining a sufficient supply for health. Supermarkets carry plant-based meat packaged with an emphasis on green and sustainable production. It promotes the value of plant-based meat in terms of its contribution to the environment.

Social responsibility is useful information for communicating with consumers and makes a product worth buying. Another proposed solution to decrease meat consumption from animals is cultured meat, which can be grown from animal cells without animal slaughter and would cause less harm to the environment in terms of greenhouse gas emissions and land and water use [27,28]. Consumer awareness surveys suggested that safety and nutritional information is important for communication with consumers for cultured meat [29–31]. Meanwhile, for alternative proteins such as insects and plant-based meat, scientific interest was an important factor influencing willingness to buy. The more interested a consumer is in scientific trends, the easier it is to access newly developed products. Knowing how they are produced would encourage consumers to try these newly introduced foods.

Regarding the importance of technology awareness, information credibility is of particular interest. There is a need for as much transparency as possible along the food production chain, to build and maintain consumer trust in food safety and regulations. Consumers wish to make an informed choice regarding their food product purchasing decisions. Consumers rely on credibility when buying a new food, and the higher the risk, the more people rely on the credibility of the product [32]. To reassure consumers and expand the market for novel foods, a certification system has been considered by many countries. National government authorities and scientific reports are rated as the most reliable sources of information [33,34], and disclosing credible information may have a significant impact on consumers' acceptance. Therefore, we assumed that awareness of GE technology and concerns about the reliability of information regarding GE foods would affect willingness to buy.

H1. Awareness of GE technology positively affects concerns about information credibility.

H2. Concerns about information credibility positively affect willingness to buy.

2.2. Effect of Technology Awareness and Perceived Usefulness on Willingness to Buy

As new technologies emerge, their content, as well as their individual health-related and social usefulness, receive increased attention. Awareness of a technology naturally leads to exploring its benefits, and consumers become interested in the usefulness of novel food technologies. The lack of understanding of technologies can lead consumers to have doubts about their usefulness, such as the positive health effects of functional foods [35]. Usefulness is an important factor in consumers' choices of foods. It is deemed that if a product solves as many issues and problems as possible and benefits as many people as possible, it will be more likely to be widely used. People tend to accept novel foods easier if they bring tangible consumer benefits [36]. Consumers who are sensitive to environmental and quality issues are willing to pay a premium for quality food; for example, organic wine with no added sulfites is required for effective price differentiation [37]. Animal welfare and environmentally enhanced cultured meat showed statistically significant positive effects for consumer attitude [38]. Environmental concerns and subjective norms have a significant positive effect on consumers' attitudes and purchase intentions towards microalgae-based food [39]. At the same time, consumers look for certificates to reassure themselves about the information of the usefulness of foods. Pricing represents the reliability of the product when buying novel foods in a supermarket [32]. High-priced foods could be perceived as good quality foods by consumers. Consumers also care about the source of information of novel foods' usefulness [40]. Nutritional or health issues of foods are often referred to by government authorities, scientific reports, or newspapers. Based on this background, we developed the following hypotheses.

H3. Awareness of GE technology positively affects interest in perceived usefulness.

H4. Interest in perceived usefulness positively affects willingness to buy.

H5. Concerns about information credibility positively affect interest in perceived usefulness.

3. Materials and Methods

3.1. Data Collection

An anonymous survey was administered to 550 respondents in their twenties to seventies living in Japan in August 2021 (Table 1). The survey was conducted via the Internet. The online survey was exclusively conducted among respondents who provided their subjective consent. We provided an introductory explanation that included information about genome-edited (GE) food technology. Participants were classified into two categories based on subjective criteria of whether they understood or did not understand GE foods, and only the samples who indicated an understanding of GE foods proceeded to respond. Based on the regulations of the Research Ethics Committee of Tokyo University of Science for Medical and Biological Research Involving Human Subjects, this study is not subject to informed consent and ethical review, because it contained no questions that could cause psychological trauma. Questionnaire items were developed by referring to previous reports [41,42]. A 5-point scale was used for the questions on genome-edited foods.

	Percentage out of 550 Respondents
Gender	
Men	48.5
Women	51.5
Age	
20~29	12.0
30~39	21.0
40~49	25.0
50~59	25.0
60~69	14.0
70 and above	3.0
Career	
Government employee	5.6
Manager/Executive	2.2
Company employee (clerical)	17.8
Company employee (technical)	11.3
Company employee (other)	14.4
Self-employed	4.7
Freelance	1.6
Homemaker	14.9
Temporary worker	11.8
Student	1.8
Others	2.0
Unemployed	11.8

Table 1. Sample distribution.

3.2. Genome-Edited Foods Acceptability Model

A GE foods acceptability model was built by using structural equation modeling (SEM). The analysis was conducted using SPSS Amos17 (SPSS Inc., Armonk, NY, USA). GFI, AGFI, and RMSEA were employed as goodness-of-fit indexes to confirm the accuracy of the model.

4. Results

Genome-Edited Foods Acceptance Model

An exploratory model of GE food acceptance was built by using each potential variable set (Table 2). Four latent variables were extracted: willingness to buy GE foods, perceived usefulness, information credibility, and awareness of GE technology, and these showed enough convergent validity based on Cronbach's alpha (>0.81). The means and standard deviations ranged from 1.91 to 2.92, and 0.955 to 1.08, respectively, illustrating a relatively low awareness of GE technologies. In addition, we conducted an assessment of reliability and validity using measures such as average variance extracted (AVE), composite reliability (CR), and maximum shared variance (MSV) (Table 2), as well as examined the correlations between the latent variables (Table 3).

Latent Variable	Observed Variable	М	SD	α	AVE	CR	MSV
Willingness to buy genome-edited foods	Willingness to buy 1	2.73	1.03				
	Willingness to buy 2	2.71	1.02	0.963	0.89	0.96	0.26
	Willingness to buy 3	2.75	1.08	_			
Perceived usefulness	Perceived usefulness 1	2.73	1.01				0.22
	Perceived usefulness 2	2.58	0.96	0.887	0.75	0.90	
	Perceived usefulness 3	2.90	0.96	_			
Information credibility	Information credibility 1	2.92	0.98	0.011 0.70		0.82	0.14
	Information credibility 2	2.74	1.01	- 0.011	0.70	0.82	0.14
Awareness of genome editing technology	Awareness 1	1.91	1.05				
	Awareness 2	1.96	1.04	_			
	Awareness 3	1.94	1.05	0.956	0.81	0.95	0.39
	Awareness 4	1.96	1.01	_			
	Awareness 5	2.00	1.06	_			

Table 2. Latent variables and observed variables.

Table 3. Correlations of latent variables.

	Willingness to Buy Genome-Edited Foods	Perceived Usefulness	Information Credibility	Awareness of Genome Editing Technology
Willingness to buy genome-edited foods	1	0.786	0.860	0.180
Perceived usefulness		1	0.941	0.227
Information credibility			1	0.209
Awareness of genome editing technology				1

The model illustrated the relationship between the latent variables (Figure 1). Awareness of genome editing technology influenced information credibility (0.201, <0.001) but not perceived usefulness (0.055, p = 0.041). Perceived usefulness should closely be related with information credibility (0.821, <0.001). Information credibility (0.201, <0.001) and perceived usefulness (0.679, <0.001) significantly affected willingness to buy GE foods. In addition, we estimated Cronbach's alpha for each latent variable as a way to examine the validity of the data in this study, and the standards for all latent variables were met (Table 4).



Figure 1. Genome-edited foods acceptance model.

Table 4. The structural model assessment
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Path	Path Coefficient	Standard Errors	t-Value	<i>p</i> -Value
Awareness of genome-editing technology \rightarrow Information credibility	0.201	0.035	4.348	0.000
Awareness of genome-editing technology \rightarrow Perceived usefulness	0.055	0.024	2.044	0.041
Perceived usefulness \rightarrow Willingness to buy genome-edited foods	0.201	0.066	3.436	0.000
Information credibility \rightarrow Perceived usefulness	0.821	0.048	19.956	0.000
Information credibility \rightarrow Willingness to buy genome-edited foods	0.679	0.089	10.151	0.000

The goodness-of-fit indexes, that is, Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), and Root Mean Square Error of Approximation (RMSEA), confirmed in this study were GFI = 0.987 (\geq 0.9), AGFI = 0.972 (\geq 0.9), and RMSEA = 0.015 (\leq 0.1) which satisfied the conditions.

5. Discussion

5.1. Genome-Edited Foods Acceptance

The acceptance model showed that the largest path coefficient for willingness to buy GE foods was information credibility, which also indirectly positively influenced willingness to buy GE foods through interest in perceived usefulness. There is also a significant indirect path from an awareness of GE technology to a willingness to buy GE foods through information credibility and perceived usefulness. Awareness of GE technology was found to be indirectly positively related to perceived usefulness through information credibility, but insignificantly related to it directly. As far as information disclosure of GE technology is concerned, these findings suggest that technology awareness might trigger concerns about information credibility, and that information credibility would play an important role in enhancing the acceptability of GE foods. Once consumers learn about the scientific context and theory behind GE technology, that is, the production process, the next question is whether the information is reliable or not. Moreover, without reliable information, the usefulness of GE foods is negligible, even with knowledge of GE technology.

The model suggested that technology awareness could be the driver to try a new product. There are concerns that consumers may confuse GMO foods and GE foods and could react negatively when buying or consuming GE foods [15]. The changes that occur in the DNA in genome editing are changes that can occur in nature or in conventional breeding [9], which is very different from what happens in GMO foods [43]. That allows one to bring in not only certification but also information about nutrition, health issues, and other issues along with scientific proof. Until now, nutrition education has been the focus of dietary education. However, in response to rapid technological advances in recent years, guidance on newly developed food technologies should be strengthened. Hence, the relationship between food technology education and food acceptance needs further empirical investigation.

Another important issue related to information is the source. Factors affecting the perception of information reliability have been investigated and their source appears to be important. According to previous research, perception of information reliability is highly influenced by the source; in particular, the amount of perceived information each source contains about food risks is an important factor, as is the degree of concern consumers believe that agencies have about protecting their health from food risks. For example, governmental agencies, educational institutions, or primary physicians could be good sources [44,45]. Perception of information credibility also affects food choice behavior. Previous studies have noted the importance of information credibility in helping consumers make healthier food choices [46,47]. Consumers can be reassured by trusted certificates on safety and health issues and then purchase them. Certified labelling has been used to communicate with consumers to reassure them of the source and its reliability. Food labels have shown their positive influence on consumers' choices; for example, organic labels and functional food labels are effective in promoting those foods [48,49]. Regarding GE foods, a survey of Twitter posts in Japan also indicates a strong desire for mandatory labeling [50].

The path from perceived usefulness to willingness to purchase is also significant, indicating that promoting the usefulness of GE foods directly leads to a willingness to purchase. The findings were also true for new food services and new foods boosted by newly developed technologies. For example, perceived usefulness was found to be a major predictor of service adoption in drone delivery food services [51]. It is an important determinant of consumer intention to purchase traceable meat [52]. Consumers in Australia, Brazil, and Canada agree that GMO foods help solve environmental problems such as food security [15]. They show that the higher the level of agreement with the idea that GMO foods can help solve environmental problems such as food security, the higher the amount of willingness to consume the food.

Perceived usefulness is an important factor in consumer purchase intentions. Consumers are more willing to purchase a product if they are convinced of its health promotion capabilities [53]. As genome editing technology targets the process of conventional breeding, besides its nutrition-related benefits, knowledge of its contribution to the food industry would be a valuable piece of information. For example, tomatoes containing high levels of gamma-amino butyric acid (GABA), which has been found to lower blood pressure, went on sale in 2021 in Japan [54]. Inspired by beef cattle that are naturally occurring mutants of the myostatin gene with increased skeletal muscle mass, the red sea bream and tiger puffer fish were bred with disrupted myostatin. This resulted in the successful production of the fleshier red sea bream and tiger puffer fish, with 1.5 to 2 times the muscle mass [55]. Therefore, to disseminate such benefits, it would be effective to segment target groups.

Of note is the low average of responses to questions regarding GE foods. It suggests that respondents have a low level of awareness and a generally negative attitude towards GE foods. In light of these results, it is important to enhance purchase intention by delivering information about genome editing technology and its benefits, as proposed in this study. Additionally, conducting segmentation based on levels of purchase intention and extracting consumer characteristics and needs from each segment will allow for the development of tailored marketing strategies. It is crucial to formulate precise marketing strategies in order to address these specific consumer segments and enhance purchase intention. Amidst the diversification of communication channels, it is crucial to select channels based on consumer segments [56]. For instance, consumers who exhibit a high interest in new products and technologies are likely to be receptive to novel information, making digital marketing an effective approach. Particularly, the proposed model in this study indicates that the perception of usefulness, encompassing contributions to food supply stability and health promotion, has a positive impact on purchase intentions. This aligns with the current trend of heightened consumer interest in environmental considerations and sustainability in food products [57]. Emphasizing these aspects through effective marketing communication tools such as advertising and package's label designs can prove to be effective in enhancing purchase intentions.

5.2. Limitations

This study explored the factors of GE foods' acceptability in Japan and developed a relevant GE foods acceptability model. It emphasized that the knowledge of novel technologies and the credibility of such information are important to enhance the acceptance of GE foods. This offers practical implications on how to introduce novel foods to increase their acceptance. However, the study has some limitations. First, the analysis in this study is based on a survey conducted at a time when GE foods were not well-known in Japan. An examination of the average scores in Table 2 reveals that all responses exhibit low average scores. Therefore, there could possibly be a high degree of food neophobia. Thus, this model could reflect the partial opinion of those who have a relatively high level of interest in science. Additionally, in this study, participants are providing self-assessments of their understanding of GE foods, i.e., participants were classified into two categories based on subjective criteria of whether they understood or did not understand GE foods, and only the samples who indicated an understanding of GE foods proceeded to respond. When analyzing the purchasing intention for products that are unfamiliar to consumers, such as GE foods, it is necessary to assess participants' knowledge of the specific product and use objective criteria to address any knowledge gaps. Therefore, in future research, it will be necessary to assess understandings of GE foods and include only those respondents who meet the criteria as data samples. We believe that it would be possible to construct a model that better reflects public opinion if the survey is conducted at a stage when the use of GE foods has become somewhat more widespread. It could present further perceptions. Second, care should be taken to avoid bias in respondent demographics. The survey in this study was conducted over the Internet and the respondents happened to be limited to Internet users. Thus, the characteristics of the respondents might be biased.

In order to achieve a sustainable food supply, the introduction of new technologies that ensure environmentally friendly production and high yields is essential. Within this context, new food products are continually being developed, and consumers are beginning to consider incorporating these new foods into their regular diets. However, due to a lack of awareness about new food products, many consumers hesitate to make purchases due to safety concerns and pricing considerations. Therefore, as indicated by the consumer demand for reliable information highlighted in this study, effective consumer communication is crucial prior to the introduction of new food products. It has been observed that information disclosure positively influences the acceptance of various food products [58,59]. Therefore, it is crucial for GE foods to carefully consider strategies for information disclosure, including prioritizing the content related to technology, safety, and nutritional benefits, as well as the methods and duration of information disclosure. Such efforts are expected to provide valuable insights that contribute to the realization of a sustainable agricultural and food industry in the future.

6. Conclusions

We analyzed the consumer acceptance of genome-edited (GE) foods in Japan. In this study, we formulated hypotheses, and constructed and verified an acceptability model. Based on the constructed GE food acceptability model, awareness of GE technology would be essential to encourage consumers' acceptance, which is mediated by information credibility and perceived usefulness of GE foods. This suggests the need for effective information disclosure, including food technology education. These efforts would contribute to future food security and the sustainable development of the food industry.

Author Contributions: Design, Y.S.; formal analysis, R.S.; writing, R.S.; supervision, Y.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available in the dryad repository: https://datadryad.org/stash/share/eDDtaiI99C0e6iI6k_Sq-I1hBf7 5oDA8T2Lge569tws (reviewer URL) (accessed on 9 November 2022).

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

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