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Providing appropriate information to consumers boosts the acceptability of genome-edited foods in Japan

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ABSTRACT

The Japanese Health Ministry recently granted permission for the market distribution of genome-edited (GE) foods, yet there remains a lack of full understanding among consumers regarding this technology. In this study, we conducted a survey to assess the acceptability of GE foods among Japanese consumers and examined the impact of providing information about GE foods on their acceptability. We conducted a web-based survey among 3,408 consumers aged 20–69 years, focusing on three aspects: (1) the commercial availability of GE foods, (2) the consumption of GE foods by others, and (3) your own consumption of GE foods. The survey findings revealed that participants were most accepting of the consumption of GE foods by others, followed by their acceptance of GE foods being commercially available. Notably, participants' acceptance of GE foods increased in all three aspects after they viewed an informative video. The video had a particularly strong impact on participants who fully or partially understood its content, compared to those who did not. Furthermore, regression analyses showed that participants' understanding of two key areas, namely "Why are GE foods important" and "What procedures are in place to ensure the safety of GE foods," played a crucial role in increasing acceptability. Overall, these results indicate that providing information about GE foods to Japanese consumers can effectively enhance their acceptance of such foods. The findings highlight the importance of understanding the benefits and safety measures associated with GE foods in influencing consumer attitudes.

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Acceptability; genome-edited foods; information provision; perception

Introduction

Genome editing technology is rapidly advancing and is recognized as an effective breeding method for developing crops with novel traits. In 2019, the Japanese Ministry of Health, Labor and Welfare (MHLW) released the Food Hygiene Handling Procedures for Food and Additives Derived from Genome Editing Technology (https://www.mhlw.go.jp/content/000550824.pdf), which allowed the market distribution of genome-edited (GE) products that could be verified to contain no foreign DNA.[1–3] Under this regulation, developers are required to submit a notification form to the MHLW, and upon completion of the pre-submission consultation and notification process, four types of GE foods have been approved for market distribution as of April 2023. These include γ-aminobutyric acid (GABA)-rich tomatoes,[4] red sea bream with increased muscle mass,[5] tiger pufferfish with increased body weight,[6] and waxy maize.[7] The MHLW publishes all notification forms on the website (https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/kenkou_iryou/shokuhin/bio/genomed/newpage_00010.html). However, despite regulatory approval, the acceptance of GE foods among Japanese consumers remains low. A survey conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2019 evaluated the social acceptability of 18 new technologies among 3,000 Japanese respondents. The survey revealed that the social acceptance of GE foods in Japan was less than 40%, ranking it as the fourth least accepted technology among the 18 assessed.[8] To facilitate the widespread adoption of GE foods, there is a pressing need to improve consumers' understanding and acceptance of these products.

A large number of studies have been conducted worldwide to investigate consumer attitudes

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toward GE foods.[9–13] Comparisons between GE foods and genetically modified (GM) foods have indicated that consumers generally hold a higher valuation for GE foods.[14–18] Both GE and GM foods offer a wide range of potential benefits, including enhanced agronomic performance (such as disease resistance, drought tolerance, and high yields), and improved final product quality (such as nutrition and shelf life), as well as increased resilience to climate change.[19] However, the average cost and development time for GE foods are estimated to be significantly lower than those for GM foods. Consequently, the development of GE foods with diverse benefits is expected to accelerate. Studies have indicated that consumer acceptance of GE foods is influenced by perceptions of their social, environmental, and personal benefits.[20,21] In a study examining the acceptability of GM foods in Japan, it was found that benefit perceptions had a greater impact on social acceptability (i.e., commercial availability) than on personal acceptability (i.e., individual consumption).[22] While consumer acceptability of GE foods may vary based on specific aspects, the social and personal acceptability of these foods has yet to be comprehensively examined. Examining different aspects of consumer acceptance toward GE foods would provide more detailed insights into consumer attitudes and preferences regarding these products.

Several studies examining consumer acceptance or rejection of GM foods have consistently highlighted the significance of scientific knowledge in shaping a higher level of acceptability.[23–29] These studies have demonstrated that consumers who possess the necessary knowledge to comprehend GM foods are more likely to accept them. Similarly, research on GE foods has also focused on enhancing consumers' scientific knowledge through information provision.[9,30,31] A previous study investigating the factors influencing the acceptance of GE foods among young Japanese individuals emphasized the importance of improving their scientific knowledge and highlighted the positive impact of science communication in fostering trust in GE foods.[9] However, we do not know what specific scientific knowledge contributes to greater consumer acceptance. Therefore, it is crucial to identify the specific scientific knowledge that effectively enhances consumer acceptance of GE foods. This clarification of the pertinent scientific knowledge could significantly contribute to bolstering consumer acceptance of GE foods.

To achieve two specific objectives, we developed an original video that provides a comprehensive and easily understandable explanation of GE foods. Subsequently, we conducted a survey to assess consumer attitudes toward GE foods. The first objective was to evaluate the acceptability of GE foods among Japanese consumers across three dimensions: (1) the commercial availability of GE foods, (2) the consumption of GE foods by others, and (3) your own consumption of GE foods. The second objective was to investigate the impact of information on the acceptability of GE foods and to identify effective content that can enhance the acceptability of GE foods.

The study shows the participants' initial level of acceptability toward GE foods, both before and after watching an explanatory video on GE foods. Then it examines the changes in acceptability based on two factors: the participants' initial level of knowledge and their understanding of the information provided in the video. Finally, the study identifies the specific content within the video that proves effective in increasing the acceptability of GE foods.

Methods

From December 2021 to January 2022, a web-based survey was conducted in collaboration with an Internet research firm, NTT Com Online Marketing Solutions, Inc. The purpose of the survey was to gather valuable insights into consumer perspectives. The survey, titled "Questionnaire on Food," was conducted on individuals willing to participate, reflecting a balance of gender and age groups. A total of 3,408 consumers aged 20–69 completed the survey. Participants were asked to provide information necessary to conduct the demographic analysis, including gender and age. In addition, participants were asked to rate their level of knowledge in two key areas: biology and GE foods. This assessment was intended to measure participants' perception and understanding of this topic.

In this survey, participants were shown an original video from our website, which explained GE foods. The video aimed to provide visual and easily comprehensible information about GE foods, a concept unfamiliar to the average consumer. The video, available in Japanese (http://www.nihs.go.jp/dnfi/mp4/GE_Basic1.mp4) and with an English explanation (http://www.nihs.go.jp/dnfi/mp4/GE_Basic1_En.mp4), had a duration of 5 minutes. The video covered five main topics: "What is the difference between GM and GE foods?", "How does GE technology work?", "Why are GE foods important?", "What are some beneficial GE foods?", and "What procedures are in place to ensure the safety of GE foods?" The topic "What is the difference between GM and GE foods?" explained the distinction between these two types of food and how they manipulate genes. "How does GE technology work?" clarified the process of altering an organism's properties by targeting and modifying endogenous specific genes. "Why are GE foods important?" provided insights into what sets GE foods apart from other food types. "What are some beneficial GE foods?" discussed current and future examples of GE foods that offer benefits. "What procedures are in place to ensure the safety of GE foods?" explained the safety evaluation measures that GE foods undergo before entering the market. Participants completed the questionnaire about GE foods both before and after viewing the video. Their acceptance of GE foods was evaluated based on three aspects: (1) the commercial availability of GE foods, (2) the consumption of GE foods by others, and (3) your own consumption of GE foods. Responses were recorded on a 7-point semantic differential scale, ranging from 1 (unacceptable) to 7 (acceptable). Additionally, participants' comprehension of the video content was assessed using a 4-point scale, ranging from "difficult to understand" to "fully understandable."

All statistical analyses were conducted using IBM SPSS (ver. 28). The data concerning participants' acceptability of GE foods did not follow a normal distribution, as determined by the Kolmogorov–Smirnov test. Therefore, nonparametric statistical analyses were employed. However, means are presented in Tables 3, 5, and 7, as the median values on the 7-point scale failed to capture slight differences among the datasets. To assess relationships between variables, Spearman's correlation coefficients were calculated. The Friedman test, followed by post hoc tests with Bonferroni correction for multiple comparisons, was employed to examine differences among the three aspects of acceptability. The Wilcoxon signed-rank test was used to determine significant differences in acceptability before and after watching the video. The Kruskal–Wallis test, along with post hoc tests using Bonferroni correction, was conducted to evaluate differences in acceptability among independent groups. Linear regression analyses were performed to investigate the relationships between changes in acceptability for GE foods and participants' understanding of the video content. For all analyses, a significance level of $p < .05$ was considered statistically significant.

Results

This survey aimed to assess consumers' acceptance of GE foods and identify effective content to enhance their acceptability. The demographic characteristics of the 3,408 participants are summarized in Table 1. Among the participants, 23% demonstrated a high or moderate level of knowledge in biology, including genetics. Additionally, 17% of the survey respondents reported having a moderate to good understanding of GE foods.

Table 2 and Fig. 1 show the participants' acceptance of GE foods before and after viewing the video. Prior to watching the video, the statistical distributions of the three aspects of acceptability differed significantly ($p < .001$). The highest level of acceptability was observed in the aspect of "consumption of GE foods by others" (i.e., acceptance of consuming GE foods by others),' followed by "commercial availability of GE foods" (i.e., whether GE foods are commercially accessible in a market). The lowest level of acceptability was found in the aspect of "your own consumption of GE foods" (i.e., personal acceptance of consuming GE foods).

Furthermore, our study presents the changes in each aspect of GE food acceptability after watching the video, categorized by gender, age, knowledge of biology, and knowledge of GE foods (Table 3). Before watching the video, males exhibited higher levels of acceptability compared to females

Table 1. Demographics of participants.

	n	%
Total	3,408	100%
Gender		
Male	1,713	50%
Female	1,695	50%
Age		
20–29 years	646	19%
30–39 years	690	20%
40–49 years	680	20%
50–59 years	694	20%
60–69 years	698	20%
Knowledge of biology		
High	83	2%
Moderate	705	21%
Low	1,285	38%
None	1,335	39%
Knowledge of GE foods		
High	74	2%
Moderate	501	15%
Low	1,488	44%
None	1,345	39%

($p < .001$). Additionally, acceptability decreased with increasing age from the 20s to the 60s ($p < .001$). Participants with higher levels of biology knowledge demonstrated the highest acceptance among the four groups ($p < .001$). Similarly, participants with a good understanding of GE foods exhibited the highest acceptance among the four groups ($p < .001$). Next, the study compared the three aspects of acceptability before and after participants watched the video. The information presented in the video effectively increased participants' acceptance of GE foods. Providing appropriate and easy-to-understand information resulted in a 53% increase in acceptance of "commercial availability of GE foods," a 47% increase in acceptance of "consumption of GE foods by others," and a 49% increase in acceptance of "your own consumption of GE foods" (Table 4). The video presented a strong impact on enhancing all three aspects of acceptability, particularly among participants with limited scientific knowledge of GE foods (Table 3).

Table 5 presents the changes in GE food acceptability after participants watched the video, categorized into four groups based on their level of understanding of the video's contents. When comparing before and after watching the video, three of the four groups (excluding the difficult to understand group) showed increased acceptance of GE foods across all content ($p < .001$). However, the difficult to understand group did not exhibit increased acceptance, except for the content explaining the beneficial GE foods. Furthermore, when comparing the increase in GE food acceptability after watching the video ("After-Before") among the four groups based on their level of understanding, participants who fully or partially understood the video's contents demonstrated a greater increase in acceptability compared to those who had difficulty understanding ($p < .001$, respectively).

Additionally, linear regression analyses were conducted to identify the content that effectively increased the acceptance of GE foods (Table 6). The explanatory variables included in the regression model were gender, age, and understanding in five specific topics. All three models provided statistically significant results. The analyses revealed that understanding two specific areas, namely, "Why are GE foods important?" and "What procedures are in place to ensure the safety of GE foods?," played a vital role in increasing acceptance across all three aspects of GE food acceptability ($p < .001$ and $p < .05$, respectively).

Table 7 compares the changes in the acceptability of GE foods with the changes in fear of GE foods after watching the video. Following the video, 35% of the survey participants reported a decrease in their fear of GE foods, while 47% had no change, and 18% reported an increase in their fear of GE foods. Interestingly, even among those individuals whose fear of GE foods did not decrease, there was an observed increase in the acceptability of GE foods ($p < .001$).

Table 2. The participants acceptability for GE foods before and after watching the video explaining GE foods in terms of three aspects.

	(1) Commercial availability of GE foods		(2) Consumption of GE foods by others		(3) Your own consumption of GE foods			
	n	%	n	%	n	%	*p* value (among three aspects)	Multiple comparisons
Before (baseline)								
1: unacceptable	344	10%	269	8%	432	13%	<0.001	(2)>;(1), (2)>;(3), (1)>;(3) ($p < .001$)
2	342	10%	271	8%	393	12%		
3	584	17%	495	15%	567	17%		
4	1,638	48%	1,790	53%	1,515	45%		
5	289	9%	343	10%	301	9%		
6	124	4%	121	4%	112	3%		
7: acceptable	87	3%	119	4%	88	3%		
After								
1: unacceptable	169	5%	140	4%	228	7%	<0.001	(2)>;(3), (1)>;(3) ($p < .001$)
2	139	4%	117	3%	196	6%		
3	316	9%	332	10%	391	12%		
4	1,267	37%	1,327	39%	1,253	37%		
5	816	24%	790	23%	711	21%		
6	467	14%	455	13%	415	12%		
7: acceptable	234	7%	247	7%	214	6%		
p value (between Before and After)	<0.001		<0.001		<0.001			

The acceptability of GE foods was investigated in terms of three aspects: (1) commercial availability of GE foods, (2) consumption of GE foods by others, and (3) your own consumption of GE foods. Responses were measured on a 7-point semantic differential scale from 1 (unacceptable) to 7 (acceptable).

Differences among three aspects of acceptability were tested by the Friedman test and post hoc tests with Bonferroni correction for multiple comparisons.

Differences in acceptability from before to after watching the video were determined with the Wilcoxon signed rank test.

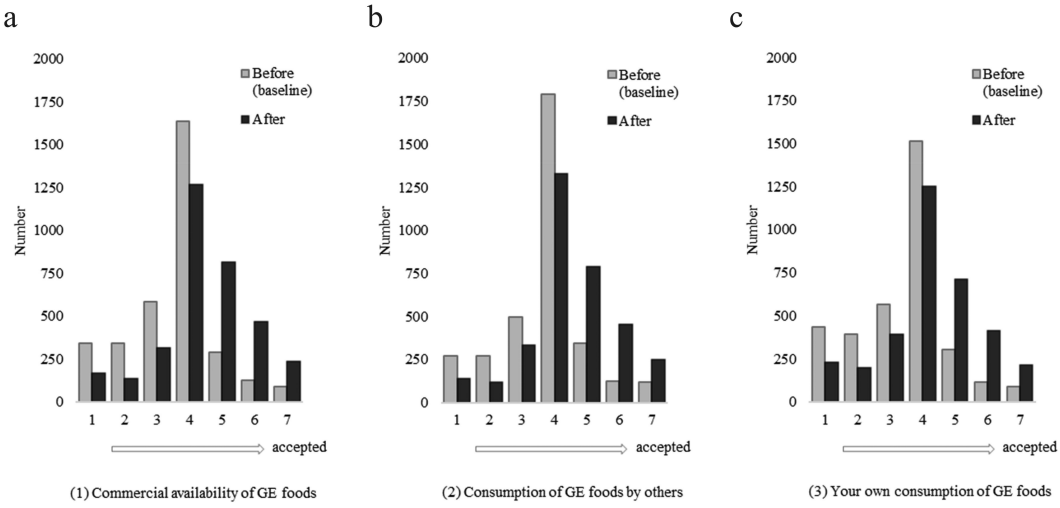

Figure 1. The participants' acceptance of GE foods before and after watching the video that explains what GE foods are. Histogram of the acceptability of "commercial availability of GE foods" (a), "consumption of GE foods by others" (b), and "your own consumption of GE foods" (c). The responses were measured on a 7-point semantic differential scale from 1 (unacceptable) to 7 (acceptable).

Discussion

We investigated the relationship between the acceptability of GE foods and the information provided to Japanese consumers. The results demonstrated variations in the acceptability of GE foods across the three aspects studied and indicated that adequate information contributed to an increase in the acceptability of GE foods.

Scientific knowledge plays a crucial role in shaping consumer attitudes toward technology. A recent review analyzing consumer attitudes toward novel foods produced with new plant engineering techniques (NPETs), including genome editing, highlighted that higher levels of knowledge in science and technology foster the acceptance of NPETs and NPET-derived products.[32] Previous surveys have reported that consumer knowledge of GE foods is generally limited,[10,20] and awareness of GE foods varies across different countries. A 2019 survey conducted across all 28 EU member states at that time found that the highest percentage of participants who had heard about GE foods was in Finland (62%) and Estonia (57%), while the lowest percentages were observed in Italy (8%) and Slovakia (8%).[33] In our study population, 17% of participants reported having high or moderate scientific knowledge of GE foods (Table 1). Other surveys conducted in Japan have also revealed a lack of knowledge regarding GE foods (https://mhlw-grants.niph.go.jp/system/files/2019/193031/201924008A_upload/201924008A0005.pdf, https://cbijapan.com/wp-content/uploads/2022/03/2021_CBIJ_Consumer_Survey_on_GM.pdf). Consumers need to be sufficiently informed about GE foods to make objective decisions regarding their acceptance.

This study revealed differences in the acceptability of GE foods across the three aspects examined, with "your own consumption of GE foods" being the lowest (Table 2 and Fig. 1), indicating that consumers are most cautious when it comes to their personal food intakes. A recent study reported that consumers' reluctance to consume GE foods was associated with neophobic preferences.[34] Neophobia, which refers to a fear of novelty, may arise from a lack of knowledge or information about the technologies involved and can be addressed through increased consumer education.[35]

Regarding scientific knowledge of GE foods, no baseline differences were observed among the three acceptability categories for participants with a high level of knowledge, and these participants exhibited greater overall acceptance of GE foods (Table 3). This finding suggests that individuals who possess knowledge about GE foods are supportive not only of their availability but also of their personal consumption. Many studies have reported a correlation between negative attitudes toward GM foods and a lack of knowledge about them.[24,36,37] Similarly, negative attitudes toward GE foods may

Table 3. Changes in the acceptability of GE foods after watching the video by gender, age, knowledge of biology, and knowledge of GE foods.

		(1) Commercial availability of GE foods			(2) Consumption of GE foods by others			(3) Your own consumption of GE foods			
	n	Before (baseline)	After		Before (baseline)	After		Before (baseline)	After		*p* value (among three aspects at baseline)
Total	3,408	3.6	4.4	***	3.7	4.4	***	3.5	4.2	***	<0.001
Gender											
Male	1,713	3.8a	4.4	***	3.9a	4.5	***	3.7a	4.3	***	<0.001
Female	1,695	3.4b	4.4	***	3.6b	4.4	***	3.3b	4.2	***	<0.001
Age											
20–29 years	646	3.9a	4.5	***	4.1a	4.5	***	3.9a	4.4a	***	<0.001
30–39 years	690	3.7b	4.3	***	3.8b	4.3	***	3.6b	4.1b	***	<0.001
40–49 years	680	3.5bc	4.4	***	3.7bc	4.5	***	3.4bc	4.2ab	***	<0.001
50–59 years	694	3.4c	4.4	***	3.7bc	4.4	***	3.3 cd	4.1b	***	<0.001
60–69 years	698	3.3c	4.5	***	3.5c	4.5	***	3.1d	4.2ab	***	<0.001
Knowledge of biology											
High	83	4.4a	4.8a	***	4.6a	4.8a	***	4.5a	4.8a	***	0.028
Moderate	705	3.6b	4.4ab	***	3.9b	4.5ab	***	3.5b	4.2ab	***	<0.001
Low	1,285	3.5c	4.4ab	***	3.7c	4.4b	***	3.3c	4.2b	***	<0.001
None	1,335	3.6b	4.4b	***	3.7c	4.4b	***	3.5bc	4.2b	***	<0.001
Knowledge of GE foods											
High	74	4.7a	4.8		4.8a	4.8a		4.8a	4.9a		0.536
Moderate	501	3.7b	4.4	***	4.0b	4.5ab	***	3.6b	4.2b	***	<0.001
Low	1,488	3.4d	4.4	***	3.6c	4.4b	***	3.3d	4.2b	***	<0.001
None	1,345	3.6c	4.4	***	3.7c	4.4b	***	3.5c	4.2b	***	<0.001

The acceptability of GE foods was investigated in terms of three aspects: (1) commercial availability of GE foods, (2) consumption of GE foods by others, and (3) your own consumption of GE foods. Responses were measured on a 7-point semantic differential scale from 1 (unacceptable) to 7 (acceptable). The data are presented as means.

Significant differences in acceptability among independent groups tested by the Mann-Whitney U test or the Kruskal-Wallis test. a–d Values not sharing a common letter are significantly different from each other at $p < .05$.

Significant differences in acceptability from before to after were tested by the Wilcoxon signed rank test. ***$p < .001$.

Differences among three aspects of acceptability were tested by the Friedman test.

Table 4. Percentages of participants whose acceptance of GE foods increased, did not change, or decreased after watching the video.

	(1) Commercial availability of GE foods	(2) Consumption of GE foods by others	(3) Your own consumption of GE foods
Decreased	6%	8%	7%
Did not change	41%	46%	44%
Increased	53%	47%	49%

The acceptability of GE foods was investigated in terms of three aspects: (1) commercial availability of GE foods, (2) consumption of GE foods by others, and (3) your own consumption of GE foods.

stem from a lack of knowledge. This study demonstrated that participants with lower levels of scientific knowledge exhibited lower baseline acceptability (Table 3), consistent with the findings of Kato-Nitta et al.,[30] who reported that perceptions and acceptance of GE foods among Japanese individuals vary based on their level of knowledge. Furthermore, participants with less scientific knowledge showed the largest increase in acceptance after receiving the information (Table 3). These results highlight the importance of providing scientific knowledge to enhance the acceptability of GE foods.

In this study, the information provided improved the overall acceptability of GE foods among participants. However, there were certain participants who did not change their views on the acceptability of GE foods after watching the video, particularly those who did not understand its contents (Table 5), except for the content explaining the beneficial GE foods. Additionally, when comparing the level of change in acceptance of GE foods based on participants' understanding levels, those who understood the video demonstrated a greater degree of change in their acceptance (Table 5). Thus, it is crucial to provide easily understandable information that aligns with consumers' knowledge levels. Given that individuals vary in their ability to understand specific information mediums, it may be effective to increase acceptance of GE foods by offering content with different levels of difficulty and allowing individuals to choose the medium (e.g., video, cartoon, etc.) that they can easily understand.

Regression analysis was conducted to identify content that effectively increased the acceptability of GE foods, revealing two independent factors: understanding "Why are GE foods important?" and understanding "What procedures are in place to ensure the safety of GE foods?" (Table 6). Regarding the importance of GE foods, the video explained that genome editing can create foods with new traits that meet the needs of developers and consumers more efficiently and in less time than conventional breeding. It has been demonstrated that not only risk and benefit perceptions but also value perceptions influence the acceptability of the technology.[30] By enhancing participants' understanding of the importance of GE foods, it is possible that value perception and acceptability of GE foods increased. Regarding the procedures taken to ensure the safety of GE foods, the video explained that experts on the Subcommittee on Genetically Modified Foods confirm that developers of GE foods conduct sufficient safety analyses during development before the foods are released in the market in Japan. These findings are consistent with a Canadian report that highlighted trust in the Canadian food safety system as an important factor influencing consumer perceptions of GE foods.[34] Increasing knowledge about safety confirmation before market distribution may enhance transparency surrounding GE foods and contribute to increased acceptance. While previous studies have emphasized the importance of increasing knowledge,[9,38] the present study provides insights into the specific knowledge that needs to be understood to improve the acceptability of GE foods.

On the other hand, it has been reported that Japanese consumers' risk perceptions of GE technology, including their understanding and feelings of fear, did not change significantly even after receiving information.[30] In our study, when comparing the level of fear of GE foods before and after information provision, 47% of participants reported no change in their degree of fear. However, even among the 18% who reported an increase in fear after receiving the information, their acceptance levels in all aspects still showed significant improvement ($p < .001$, respectively; Table 7). This indicates that even if fear does not decrease, the provision of appropriate information remains important in enhancing the acceptability of GE foods.

Table 5. Changes in the acceptability of GE foods after watching the video based on the degree of understanding the video contents.

		(1) Commercial availability of GE foods				(2) Consumption of GE foods by others				(3) Your own consumption of GE foods			
	n	Before	After		After-Before	Before	After		After-Before	Before	After		After-Before
What is the difference between GM and GE foods?													
Fully understandable	872	3.6	4.9	***	1.3a	3.9	4.9	***	1.0a	3.5	4.6	***	1.2a
Understandable to some extent	1,962	3.5	4.3	***	0.8b	3.7	4.4	***	0.7b	3.4	4.2	***	0.7b
Difficult to understand to some extent	437	3.7	4.0	***	0.3c	3.7	4.0	***	0.3c	3.6	3.8	***	0.2c
Difficult to understand	137	3.5	3.5		0.1c	3.5	3.6		0.1c	3.4	3.5		0.1c
How does GE technology work?													
Fully understandable	778	3.7	5.0	***	1.3a	4.0	5.0	***	1.1a	3.6	4.7	***	1.2a
Understandable to some extent	2,018	3.5	4.4	***	0.9b	3.7	4.4	***	0.7b	3.4	4.2	***	0.8b
Difficult to understand to some extent	468	3.6	3.9	***	0.3c	3.8	4.0	***	0.3c	3.6	3.9	***	0.3c
Difficult to understand	144	3.4	3.5		0.2c	3.4	3.6		0.2c	3.3	3.5		0.2c
Why are GE foods important?													
Fully understandable	739	3.7	5.1	***	1.4a	4.0	5.2	***	1.2a	3.6	4.9	***	1.3a
Understandable to some extent	1,969	3.5	4.4	***	0.9b	3.7	4.4	***	0.7b	3.4	4.2	***	0.8b
Difficult to understand to some extent	534	3.5	3.8	***	0.3c	3.7	3.9	***	0.2c	3.5	3.7	***	0.2c
What are some beneficial GE foods?													
Fully understandable	617	3.8	5.1	***	1.3a	4.0	5.2	***	1.1a	3.7	4.9	***	1.3a
Understandable to some extent	1,905	3.5	4.4	***	0.9b	3.7	4.4	***	0.7b	3.4	4.2	***	0.8b
Difficult to understand to some extent	692	3.5	4.0	***	0.5c	3.7	4.1	***	0.4c	3.5	3.8	***	0.4c
Difficult to understand	194	3.2	3.4	**	0.3d	3.4	3.6	*	0.2c	3.1	3.3	**	0.2c
What procedures are in place to ensure the safety of GE foods?													
Fully understandable	691	3.7	5.1	***	1.4a	4.0	5.1	***	1.2a	3.6	4.9	***	1.3a
Understandable to some extent	2,032	3.5	4.4	***	0.8b	3.7	4.4	***	0.7b	3.4	4.2	***	0.8b
Difficult to understand to some extent	536	3.6	4.0	***	0.4c	3.8	4.0	***	0.2c	3.6	3.8	***	0.3c
Difficult to understand	149	3.3	3.4		0.1d	3.4	3.4		0.1c	3.2	3.3		0.1c

The acceptability of GE foods was investigated in terms of three aspects: (1) commercial availability of GE foods, (2) consumption of GE foods by others, and (3) your own consumption of GE foods. Responses were measured on a 7-point semantic differential scale from 1 (unacceptable) to 7 (acceptable). The data are presented as means.

Significant differences in acceptance from before to after were tested by the Wilcoxon signed rank test. ***$p < .001$, **$p < .01$, *$p < .05$.

Significant differences in the change of acceptability among independent groups tested by the Kruskal-Wallis test and post hoc tests with Bonferroni correction for multiple comparisons. a–d Values not sharing a common letter are significantly different from each other at $p < .05$.

Table 6. Linear regression analyses to identify effective contents to contribute to increasing acceptability of GE foods.

	Changes in the acceptability of											
	(1) commercial availability of GE foods				(2) consumption of GE foods by others				(3) your own consumption of GE foods			
Variables	B	β	p	95% CI	B	β	p	95% CI	B	β	p	95% CI
Constant	−1.42		***	[−1.64,-1.19]	−1.27		***	[−1.49,-1.05]	−1.36		***	[−1.59,-1.13]
Gender	0.32	0.12	***	[0.24,0.40]	0.29	0.12	***	[0.21,0.37]	0.28	0.11	***	[0.20,0.36]
Age	0.10	0.11	***	[0.07,0.13]	0.09	0.10	***	[0.06,0.12]	0.10	0.11	***	[0.07,0.13]
Understanding in												
"What is the difference between GM and GE foods?"	0.08	0.05		[−0.02,0.18]	0.02	0.01		[−0.08,0.12]	0.07	0.04		[−0.03,0.18]
"How does GE technology work?"	−0.01	−0.01		[−0.12,0.10]	−0.05	−0.03		[−0.16,0.06]	−0.07	−0.04		[−0.19,0.04]
"Why are GE foods important?"	0.36	0.21	***	[0.25,0.46]	0.29	0.18	***	[0.20,0.39]	0.27	0.16	***	[0.17,0.37]
"What are some beneficial GE foods?"	−0.05	−0.03		[−0.15,0.04]	0.00	0.00		[−0.10,0.09]	0.03	0.02		[−0.07,0.12]
"What procedures are in place to ensure the safety of GE foods?"	0.12	0.07	*	[0.01,0.24]	0.16	0.10	**	[0.06,0.27]	0.17	0.10	**	[0.06,0.28]
F			63.84***				51.22***				55.79***	
R^2			0.12				0.10				0.10	
Adjusted			0.11				0.09				0.10	

***$p < .001$, **$p < .01$, *$p < .05$.

Objective variables.

Changes in the acceptability of (1) "commercial availability of GE foods," (2) "consumption of GE foods by others," and (3) "your own consumption of GE foods" (from −6 to 6)

Explanatory variables.

Gender (0=male, 1=female).

Age (1 = 20–29 years, 2 = 30–39 years, 3 = 40–49 years, 4 = 50–59 years, 5 = 60–69 years)

Understanding in "What is the difference between GM and GE foods?," "How does GE technology work?," "Why are GE foods important?," "What are some beneficial GE foods?" and "What procedures are in place to ensure the safety of GE foods?" (1=difficult to understand, 2=difficult to understand to some extent, 3=understandable to some extent, 4=fully understandable).

Table 7. Changes in the acceptability of GE foods after watching the video based on the change in fear of GE foods.

		(1) Commercial availability of GE foods				(2) Consumption of GE foods by others				(3) Your own consumption of GE foods			
	n	Before	After	p	After-Before	Before	After	p	After-Before	Before	After	p	After-Before
Changes in the degree of fear of GE foods													
Decreased	1197 (35%)	3.5	4.7	***	1.3	3.7	4.8	***	1.1	3.3	4.5	***	1.2
Did not change	1601 (47%)	3.6	4.1	***	0.5	3.7	4.1	***	0.4	3.5	3.9	***	0.4
Increased	610 (18%)	3.7	4.5	***	0.9	3.8	4.5	***	0.8	3.6	4.4	***	0.8

The acceptability of GE foods was investigated in terms of three aspects: (1) commercial availability of GE foods, (2) consumption of GE foods by others, and (3) your own consumption of GE foods. Responses were measured on a 7-point semantic differential scale from 1 (unacceptable) to 7 (acceptable). The data are presented as means.
Significant differences in acceptability from before to after were tested by the Wilcoxon signed rank test. *** $p < .001$.

There are several limitations to this study that should be acknowledged. First, we subjectively assessed participants' knowledge of biology and GE foods, relying on self-reported measures rather than objective assessments. In studies on the acceptance of GM foods, it has been found that objective knowledge about GM foods has a greater influence on acceptance than subjective knowledge.[39] The differential effects of subjective and objective knowledge on the acceptability of GE foods are not well understood and should be considered in future research. Second, the participants in this study were limited to those registered with the survey company. While online samples are known to have inherent biases, online surveys have gained popularity in the social sciences. We attempted to balance the gender and age distribution of our sample, but we were unable to include Japanese elderly individuals aged 70 and older, as they have lower rates of digital device usage. Therefore, alternative methods beyond web-based surveys should be considered to study acceptance among older adults. Finally, our video presentation covered only five main topics, and the provided information was limited, potentially leaving some aspects of GE foods insufficiently explained. Nonetheless, our study provides valuable insights into potential content that can increase the acceptability of GE foods among Japanese consumers. Further research is needed to explore additional factors that contribute to the improvement of the acceptability of GE foods.

In conclusion, our study demonstrated that among Japanese consumers, the acceptance of GE foods varied across different aspects, with the highest acceptance observed for GE food consumption by others and the lowest acceptance for participants' consumption. Furthermore, understanding the importance of GE foods and the procedures taken to ensure their safety emerged as important factors in increasing the acceptability of GE foods across all three aspects. Unlike previous surveys conducted before the market availability of GE foods, our study was conducted after commercial availability in Japan, resulting in heightened consumer interest at the time. The findings of our study provide valuable insights for enhancing consumers' understanding and acceptance of GE foods and improving communication between developers, government authorities, and consumers.

Disclosure statement

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