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RESEARCH

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Effects of information on consumer attitudes towards gene-edited foods: a comparison between livestock and vegetables

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Abstract

Background: This study statistically explores the relationship between information provision and peoples' attitudes towards the application of gene-editing technology to food, by contrasting cases of gene-edited livestock and vegetables in Japan. Japanese food producers and researchers are optimistic about the application of the clustered regularly interspaced short palindromic repeats (CRISPR) approach to food. Due to the strict regulations regarding genetically modified (GM) food, GM crops are not commercially cultivated in Japan. Consumers worldwide have concerns about application of this technology to food. Further examination of this issue for Japanese consumers with lower acceptance towards GM food should provide essential information for global agricultural communities.

Methods: Using a web survey, split-ballot experimental design was used to randomly assign the respondents into two groups: (1) the animal group, for which information on breeding technologies, including gene editing, was provided using pig illustrations. (2) The plant group, for which information was provided using tomato illustrations. Multivariate analysis of variance and post-hoc t-tests were applied to examine the statistical differences between the plant and animal groups for attitudes towards gene-edited livestock and vegetables. Statistical analyses were conducted to examine if scientific knowledge influences these attitudes.

Results: Respondents found gene-edited vegetables more beneficial than gene-edited livestock. Their agreement was stronger for vegetables than for livestock. Respondents' attitudes towards gene-edited livestock differed depending on whether they were shown pig illustrations or tomato illustrations. The plant group scored significantly lower regarding gene-edited livestock compared to the animal group. No statistical difference was observed between the two groups in the case of gene-edited vegetables. Furthermore, the higher science literacy group always scored higher regarding improvements in vegetable breeding, but this was not concordant regarding improvements in livestock breeding.

Conclusions: People were more concerned about gene-edited livestock than gene-edited vegetables. The respondents who were provided information with tomato illustrations in advance demonstrated lower acceptance towards gene-edited livestock than those who were provided information with pig illustrations. Applying the technology to livestock, such as size enlargement for improvements, might be considered as risky by the public, in contrast with vegetables.

Keywords: Gene-edited foods, Information provision, Gene-edited animals, Science literacy, Breeding, Genetically modified food

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Background

Producing larger, tastier, and more nutritious food has always been a prime agricultural concern. Recent progress in genetic technologies, such as gene editing or a clustered regularly interspaced short palindromic repeats (CRISPR) approach has made breeding processes remarkably easier and faster. Japan, our study location, had experienced strong opposition to genetically modified (GM) crops by consumer groups in the 1990s. The Japanese government responded by setting strict regulations regarding GM crops, including the introduction of labelling regulations in 2001. Presently, there is no commercial cultivation of GM crops in Japan (ISAAA 2018). Given this situation, nowadays, the Japanese industry, government, and academia are optimistic about the application of this new gene-editing technology to food.

A recent report by the Japanese Consumer Affairs Agency (2017) stated that about 83% of Japanese survey respondents answered 'avoid' regarding GM food. Previous research statistically investigating Japanese people's attitudinal differences regarding applying conventional breeding technologies, genetic modification, and gene editing to food showed that the public perceptions regarding gene-edited crops tended to be more positive than perceptions regarding GM crops (Kato-Nitta et al. 2019). The study, however, also noted that this difference was exceedingly small compared to the difference between GM crops and conventional breeding. That is, the public in Japan tended to consider gene editing closer to genetic modification than conventional hybridisation. A report investigating US consumers indicated the same trend (FMI Foundation 2020). Furthermore, most Norwegian consumers were worried that gene-edited food is risky in relation to health and environmental issues (NBAB 2020). Because gene-editing technology has great potential for food production, further exploration of the factors associated with peoples' attitudes towards the application of this emerging technology is urgently required.

To better understand this issue, this study statistically explores the relationship between information provision and peoples' attitudes towards the application of gene-editing technology to food. This exploration is done by contrasting cases of gene-edited livestock and vegetables in Japan, where the production of GM food is strictly regulated and not generally accepted. Unfortunately, we did not find studies in the available literature that explore this topic. However, a recent research has claimed that the application of biotechnology in animal agriculture is 'controversial'. The research in question found that people's personality traits affect their opinions regarding GM animal products (Lin et al. 2019; Machado-Oliveira et al. 2020; Ardebili and Rickertsen 2020). Therefore, to shed light on public perception of gene-edited food, it is necessary to examine, with adequate control of individual factors, the influence of different information provisions on peoples' attitudes towards gene-edited animals and vegetables.

A Norwegian report (NBAB 2020) indicated that Norwegian people were apprehensive about changing the appearance of both plant and animal products by utilising gene editing. Based on this report, Japanese people would also be apprehensive to accept them. However, the question remains as to which of gene-edited animals or gene-edited plants do people feel higher apprehensiveness towards. Given that humans are animals, people generally differentiate animals from plants. Humans consider animals, including livestock, closer to humans and are more sympathetic to them than they are to plants, including vegetables. Therefore, the former holds a notion of animal welfare, which is one of the differentiations between these two species made by humans (Yunes et al. 2019). In fact, some countries including the US have set different regulations for gene-edited plants and animals (e.g. FDA 2017).

The discussion above leads to our assumption that there would be a difference in people's attitudes toward gene-edited livestock and vegetables. Hence, we measure people's assessments of the following food development goals by utilising a gene-editing technique: increasing the size of livestock/vegetables; making livestock/vegetables more resistant to disease and increasing the nutritional value of livestock/vegetables. We then examine if the type of information provision affects peoples' attitudes towards the above food development goals. The results of this research would provide empirical evidence regarding the impact of information provision on both gene-edited livestock and vegetables. This would provide valuable information to a large section of the agri-food community.

According to the contrast effect proposed in psychological literature (Sherif et al. 1958), when people are presented something having a relatively lower emotional hurdle in advance, they tend to show stronger rejection towards something that has relatively higher emotional hurdle afterwards. In this study, we presumed that when the target of gene editing was livestock or vegetables, the former would be more likely to lead people's intuitive dislike, or prove to be a higher emotional hurdle than the latter. Based on these assumptions, we derived the following hypothesis: the people who received explanation about breeding technologies with vegetable pictures in advance show lower acceptance concerning the subsequent questions on gene-edited livestock, compared to those who received explanation about breeding technologies with livestock pictures in advance. By statistically examining the above hypothesis, this study could deepen the understanding of the public perceptions of the role of innovation in food production.

The secondary purpose of this study is to statistically examine if people's scientific knowledge has any impact on the relationships between information provision and their attitudes towards gene-edited livestock/vegetables. This will deepen our understanding of the relationship between information provision and public perception toward emerging technologies. The impact of the amount of scientific knowledge people possess (science literacy) on people's risk perceptions towards emerging science, including gene editing, has been examined in vast amounts of literature (e.g. Bucchi and Neresini 2002; Kato-Nitta et al. 2019; Slovic 1999) and is still controversial (Ahteensuu 2012; Kato-Nitta 2013). Therefore, we further examine the effects of science literacy on peoples' attitudes towards the above food development goals, utilising gene-editing technology. This study's observations from the statistical analyses on information provision, science literacy, and people's attitudes towards gene-edited livestock/vegetables should further promote our understanding of public perceptions and the role of innovation in society, and thus add value to existing literature.

Methods

Data

A web-based survey was conducted in March 2018. The survey was entrusted to a survey company which holds a large opt-in panel of approximately six million people in Japan. The target population in this study is Japanese general population aged 20–69 years. The survey used a quasi-representative sample by initially screening among 61340 volunteers. A total of 6000 respondents aged between 20 and 69 years were chosen on a first-come, first-serve basis. Using a sampling frame based on an opt-in panel means having a larger coverage error compared to using a voter's list or a residential register, both of which are known to cover the entire population very well in Japanese case. To mitigate such bias in demographic distributions, the sample allocation was made in proportion to regional size, gender, and age based on the 2015 Japan national population census. Furthermore, to ensure the reliability of the data, 'satisficers' were excluded. 'Satisficers' are respondents who make decisions without applying enough cognitive effort when providing answers in a survey (Krosnick 1991; Maniaci and Rogge 2014; Tourangeau et al. 2013). Specifically, we excluded respondents who gave wrong answers to all the three directed questions scale items (DQS; Maniaci and Rogge 2014), marked multiple logically inconsistent answers, or had an extremely short total response time which was less than 1/10 of the median value. The selected final sample size had 4514 respondents. The specialised terms in the survey design and sampling described above are further explained in Appendix 1. Table 1 shows the survey demographics.

Information provision

The survey employed the split-ballot experimental design, which randomly assigns the respondents into two groups. The observed and unobserved factors of the individual respondents are adequately controlled with this randomisation procedure. The first group is the animal group, where pig illustrations were used to provide information on conventional breeding, genetic modification, and gene editing. The second is the plant group, where tomato illustrations were used to provide the same information.

All the other conditions between the two groups were the same and the same two-stage-information-provision procedures were implemented. In the first stage, the respondents were given basic textual information on the genome itself and on the agricultural applications of genome research. This stage adopted the information used in Kato-Nitta et al. (2019). In the second stage, illustrations with text were used to explain three existing breeding technologies: conventional breeding, genetic modification, and gene editing. In this stage, the respondents were shown either pig (animal group) or tomato illustrations (plant group). As such, the respondents received information on gene editing by contrasting with the other existing technologies of conventional breeding and genetic modification. The two types of illustration in Fig. 1 were shown to the respondents. The illustrations in Fig. 1 were shown respectively several times as the

Table 1 Demographic distributions

Variable	Number	Percentage (%)
Gender		
Male	2131	47.2
Female	2383	52.8
Age (years)		
20–29	574	12.7
30–39	790	17.5
40–49	994	22.0
50–59	936	20.7
60–69	1220	27.0
Education		
High school, vocational school or less	1976	43.8
Junior college, College, or above	2523	55.9
Other	15	0.3

$n = 4514$

respondents answered questions related to the application of genome research to food.

Prior to statistical analyses, we used chi-squared tests to confirm that both the samples from the animal ($n=2288$) and plant groups ($n=2226$) represent the target population to the same degree. That is, we statistically contrasted the distribution of the demographics (gender, age, and education), and there was no statistically significant difference between the two groups. Furthermore, we confirmed with chi-squared tests that there was no statistical difference between the attitudes of the two groups in terms of items located before the second stage of the provision of information. That is, there were no statistical attitudinal differences between the two groups for the questions related to genome research on agricultural products before the information provision with illustrations. The detail of such questions and their distributions are shown in Table 2. Hence, as the result of randomisation, the homogeneity of the two groups before the assignment of the experimental condition was successfully achieved; thus, the internal validity of the study was secured.

Measures and analyses

Ten items were used as dependent variables to assess various facets of perceptions regarding applying gene editing to agriculture. These items were originally developed for this survey, based on the current application of gene-editing technology to plants and non-human animals, as mentioned in previous studies (Zhang et al. 2018; de Graeff et al. 2019; Menchaca 2020). The details of the items are shown in Fig. 2. As shown in Fig. 2, these items are interpreted as the advantages of applying genome research to food.

In Fig. 2, items L1 to L5 were set as one block (Livestock block; L block), and items V1 to V5 were set as another (Vegetable block; V block). To avoid order effects, the provision of L and V blocks was randomised.

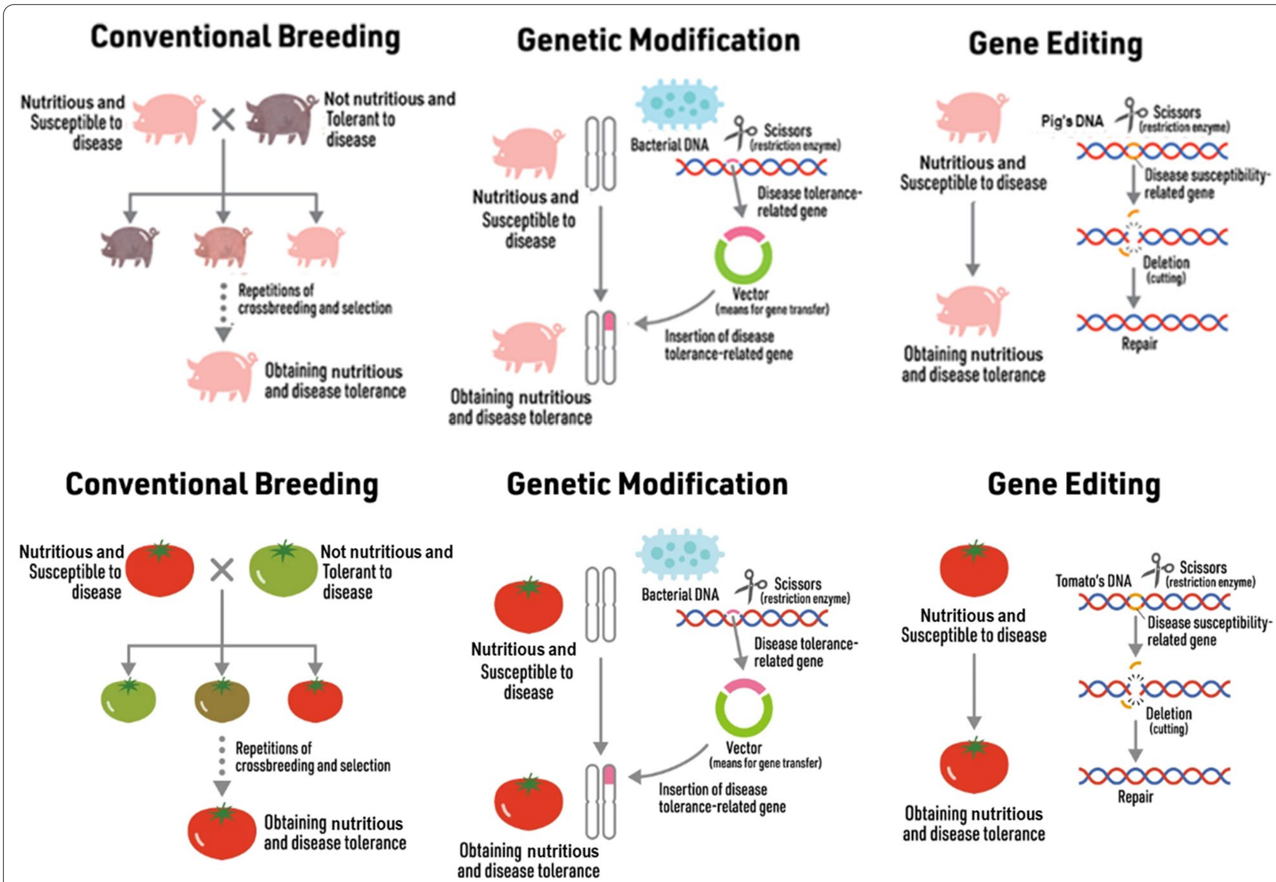

Fig. 1 Information provision with illustrations: animal group (pig illustrations) and plant group (tomato illustrations). The animal and plant groups were provided identical information. The only difference was whether they were shown pig or tomato illustrations. The text within the illustrations was also identical. The tomato illustrations were the same as the ones used by Kato-Nitta et al. (2019), and the pig illustrations were developed specifically for this survey.

Table 2 Percentages for the questions related to genome research applied to agricultural products

Questions	Categories			
Before taking this survey, did you know that genomic research has been applied to agricultural products?	I didn't know this at all	I'd heard of it	I knew a lot about it	Total
	47.5%	49.4%	3.1%	100.0%
(Animal group %, plant group %)	(48.8%, 46.1%)	(48.0%, 50.8%)	(3.2%, 3.1%)	(100%, 100%)
Are you interested in genomic research applied to agricultural products?	Yes, I'm interested	No, I'm not interested	Cannot say either way	Total
	35.8%	29.5%	34.7%	100.0%
(Animal group %, plant group %)	(35.7%, 35.9%)	(30.2%, 28.8%)	(34.2%, 35.3%)	(100%, 100%)
Would you like to know the current state of genomic research applied to agricultural products?	Yes, I'd like to know this	No, I don't want to know this	Cannot say either way	Total
	47.9%	15.3%	36.9%	100.0%
(Animal group %, plant group %)	(47.8%, 47.9%)	(15.2%, 15.3%)	(37.0%, 36.8%)	(100%, 100%)
Are you in favor of making progress in genomic research applied to agricultural products?	I am in favor of this	I am opposed to this	Cannot say either way	Total
	33.4%	7.8%	58.8%	100.0%
(Animal group %, plant group %)	(33.6%, 33.2%)	(8.3%, 7.3%)	(58.1%, 59.6%)	(100%, 100%)

$n = 4514$ (animal group $n = 2288$, plant group $n = 2226$)

Also, items within the blocks were randomised. As shown in Fig. 2, the same item-number from L and V blocks are correspondent but has only one difference depending on whether the technology application is for livestock or vegetables. All respondents answered all the ten items (L1 to V5). The respondents were asked to mark on one of the five-point scales (1 = I oppose this, 2 = I oppose this to some extent, 3 = Cannot say either way, 4 = I'm in favour to some extent, 5 = I'm in favour of this). With the above ten items, we examine if there are statistical attitudinal differences due to different information provisions of animal and plant illustrations on the application of gene editing to agriculture.

Second, we examine if science literacy influences the above ten items. To assess respondents' science literacy, 11 items with enough reliability and validity in previous studies (European Union 2001; National Science Board 2016) as well as in Japan (Ministry of Education, Culture, Sports, Science and Technology 2004; Kato-Nitta et al. 2019) were used (Appendix 2). The science literacy scale consists of items such as, 'The oxygen we breathe comes from plants: true or false'. Either 1 or 0 point for 11 items were added to yield the number-right scores. Thus, the possible lowest and highest score for this scale were 0 point and 11 points, respectively. The median value and the mean value of number-right scores in this study were 6.00 and 5.96, respectively. The correct answer rate of this scale for this study was 54.2%, just about the same with the correct answer rate of 53.6% and 54% reported in the previous surveys using the same scale in Japan

The use of gene editing technology increases the speed of breeding improvements compared to conventional technologies. In addition, the following four improvements can be made to agricultural products. First, increasing the size increases fruit flesh and meat yield. Secondly, resistance to disease can be increased. Thirdly, nutritional value can be increased. Finally, taste can be improved. With this in mind, what do you think about using gene editing technology to advance breeding improvements such as the following?

- L1 Increasing size of livestock by 20% (increase by a factor of 1.2)
- L2 Increasing size of livestock by 50% (increase by a factor of 1.5)
- L3 Making livestock more resistant to disease
- L4 Improving nutritional value of livestock
- L5 Improving the taste of livestock
- V1 Increasing size of vegetables by 20% (increase by a factor of 1.2)
- V2 Increasing size of vegetables by 50% (increase by a factor of 1.5)
- V3 Making vegetables more resistant to disease
- V4 Improving the nutritional value of vegetables
- V5 Improving the taste of vegetables

Fig. 2 Items to assess people's attitudes regarding applying gene-editing techniques to agriculture

(Kato-Nitta et al. 2019; Ministry of Education, Culture, Sports, Science and Technology 2004). Respondents who scored seven and above were categorised as having a relatively higher level of science literacy (higher science literacy group), and others were categorised as having a relatively lower level of science literacy (lower science literacy group). We further confirmed that no statistical difference was observed in both the animal and plant groups for the level of science literacy with chi-squared tests. Therefore, the samples from the animal and plant groups represent the target population as to science literacy to the same degree.

As such, we examine if any differences were observed between the animal and plant groups, as well as between higher and lower science literacy groups, based on the above ten items. The working hypotheses for the statistical tests are as follows.

Differences in information provision

H1 There is a statistical difference between the animal and plant groups regarding respondents' attitudes towards the application of gene editing to livestock.

H2 There is a statistical difference between the animal and plant groups regarding respondents' attitudes towards the application of gene editing to vegetables.

Differences in science literacy

H3 General science literacy influences respondents' attitudes towards the application of gene editing to livestock.

H4 General science literacy influences respondents' attitudes towards the application of gene editing to vegetables.

To test hypotheses H1 to H4, we first apply a two-way multivariate analysis of variance (MANOVA), simultaneously using all the dependent variables of the above ten items to examine the main effects of the two factors (information provision and science literacy). We then statistically examine the effects of information provision as well as science literacy on the respective ten dependent variables, using post-hoc between-subjects' t-tests (see also NOTE for more information on the model specification). Adoption of this two-step procedure adequately controls the experiment-wise Type-I error rate in the first step rather than requiring an adjustment of the alpha level for each comparison in the second step.

Results

Testing the main effects of information provision and science literacy with a MANOVA

A two-way MANOVA was performed with the ten items (L1 to V5) and the result showed that no interaction effects between information provision and science literacy: Wilks's $\Lambda = 0.997$, F ($df1 = 10$, $df2 = 4501$) $= 1.245$, $p = 0.256$. The main effects of information provision (group difference between the animal group and the plant group) and the science literacy were then examined and found statistically significant; results for information provision are as follows: Wilks's $\Lambda = 0.982$, F ($df1 = 10$, $df2 = 4501$) $= 8.433$, $p < 0.000$; science literacy: Wilks's $\Lambda = 0.984$, F ($df1 = 10$, $df2 = 4501$) $= 7.186$, $p < 0.000$. Because no interactions between two factors of information provision and science literacy were observed but the main effects of each factor were both observed, the post-hoc t-tests were performed to confirm the effects of each factor.

Post-hoc analyses of the attitudinal differences caused by variations in information provision

The post-hoc t-tests were performed to examine H1 and H2 on each of the ten items. Table 3 shows the results. For items L1 to L5, all the mean values of the plant group were lower than those of the animal group and were statistically significant ($p < 0.01$). That is, respondents who were shown tomato illustrations in advance found lower benefits of the application of gene-editing techniques to livestock, compared to respondents who were shown pig illustrations. The animal group scored significantly higher points than the plant group regarding gene-edited livestock. That is, respondents who were shown pig illustrations in advance found a higher level of benefits of the application of gene-editing techniques to livestock as compared to respondents who were shown tomato illustrations. On the other hand, there were no statistical differences between the two groups regarding the vegetable items of V1 to V5. The effect sizes of Cohen's d for livestock items of L1 to L5 were 0.104 to 0.130 and were relatively larger than those of vegetable items (V1 to V5, 0.002 to 0.039).

Post-hoc analyses of the attitudinal differences related to variations in the amount of science literacy

The post-hoc t-tests were performed to examine H3 and H4. Table 4 shows the results. Among items L1 to L5, there were no statistical differences between the higher science literacy group and the lower science literacy group except for one item (making livestock more resistant to disease) ($p < 0.01$). The average value of this item was higher in the higher science literacy group. People

Table 3 T-tests on the differences in the mean values of the attitudes between the plant group and the animal group towards gene-edited foods

	Item	Group	*mean*	*sd*	*df*	*t* (Welch's test)	*p*-value	Group mean difference [95% *CI*]	Cohen's *d*
L	1. Increasing size of livestock by 20% (increase by a factor of 1.2)	Plant	2.86	1.09	4495.68	3.50	0.000	0.112 [− 0.175, − 0.049]	0.104
		Animal	2.97	1.06					
	2. Increasing size of livestock by 50% (increase by a factor of 1.5)	Plant	2.70	1.10	4499.06	3.98	0.000	0.129 [− 0.192, − 0.065]	0.119
		Animal	2.82	1.07					
	3. Making livestock more resistant to disease	Plant	3.59	1.01	4493.40	4.38	0.000	0.130 [− 0.188, − 0.071]	0.130
		Animal	3.72	0.98					
	4. Improving nutritional value of livestock	Plant	3.38	1.05	4504.60	3.88	0.000	0.121 [− 0.182, − 0.060]	0.115
		Animal	3.50	1.04					
	5. Improving the taste of livestock	Plant	3.40	1.06	4504.88	4.08	0.000	0.128 [− 0.190, − 0.067]	0.122
		Animal	3.53	1.05					
V	1. Increasing size of vegetables by 20% (increase by a factor of 1.2)	Plant	3.18	1.04	4504.82	0.89	0.371	0.028 [− 0.088, 0.033]	0.027
		Animal	3.20	1.03					
	2. Increasing size of vegetables by 50% (increase by a factor of 1.5)	Plant	3.00	1.07	4503.74	1.32	0.187	0.042 [− 0.103, 0.020]	0.039
		Animal	3.04	1.05					
	3. Making vegetables more resistant to disease	Plant	3.71	0.96	4511.56	0.74	0.458	0.042 [− 0.078, 0.035]	0.022
		Animal	3.73	0.98					
	4. Improving the nutritional value of vegetables	Plant	3.69	1.01	4505.56	0.28	0.782	0.008 [− 0.067, 0.050]	0.008
		Animal	3.70	1.00					
	5. Improving the taste of vegetables	Plant	3.65	1.02	4508.52	0.74	0.947	0.002 [− 0.061, 0.057]	0.002
		Animal	3.65	1.02					

Sample size for each group: $n = 2226$ (plant group), $n = 2288$ (animal group)

with relatively higher scientific knowledge found more benefits of this aspect of gene-edited livestock. As for V1 to V5, all the items were statistically significant ($p < 0.05$), and all the average values were higher in the higher science literacy group. People with relatively higher scientific knowledge found more benefits regarding gene-edited vegetables.

Summary of the statistical tests for H1 to H4

The results of statistical tests for the hypotheses are summarised as follows. There was a statistical difference between the animal group and the plant group regarding respondents' attitudes towards all livestock items (L1 to L5). Therefore, H1 was supported. The plant group scored significantly lower regarding gene-edited livestock compared to the animal group. H2 was not supported because there was no statistical difference between the animal group and the plant group regarding respondents' attitudes regarding all the items regarding vegetables (V1 to V5). H3 was not supported except for one item (making livestock more resistant to disease). Hence, this item may be different from the other items assessing the application of gene editing to livestock in terms of the relation to scientific knowledge. H4 was supported regarding all the five vegetable items (V1 to V5).

Examination of mean differences of livestock items and their counterpart vegetable items

As is shown in Table 3, the mean values for all livestock items were lower than their counterpart vegetable items for both the animal and the plant groups. The lowest mean value observed in both groups was for the item of increasing the size of livestock by 50%. We therefore further examined if the differences in mean values of livestock items against their counterpart vegetable items were statistically significant with paired t-tests. That is, with respect to each group of the plant group and the animal group, we compared the within-subject difference between pairs of items such as L1 and V1, L2 and V2, and so on. For the plant group ($n = 2226$), the mean differences of all the paired items were statistically significant ($p < 0.000$). The effect sizes (Cohen's d) ranged from 0.181 to 0.431. For the animal group ($n = 2288$), the mean differences of all the paired items were statistically significant ($p < 0.000$; Cohen's d: 0.213 to 0.326) with the exception of one pair: making livestock/vegetables more resistant to disease ($p = 0.463$, Cohen's $d = 0.015$).

Discussion and conclusions

The results of the examination of mean differences of livestock items and their counterpart vegetable items could be interpreted to imply a tendency for people to

Table 4 T-tests on the differences in the mean values of the attitudes between the higher science literacy group and the lower science literacy group towards gene-edited foods

	Item	Group	*mean*	*sd*	*Df*	*t* (Welch's test)	*p*-value	Group mean difference [95% *CI*]	Cohen's *d*
L	1. Increasing size of livestock by 20% (increase by a factor of 1.2)	High	2.95	1.15	4112.31	1.60	0.109	0.052 [− 0.012, 0.116]	0.048
		Low	2.90	1.01					
	2. Increasing size of livestock by 50% (increase by a factor of 1.5)	High	2.76	1.17	4107.94	0.02	0.985	0.001 [− 0.064, 0.065]	0.001
		Low	2.76	1.02					
	3. Making livestock more resistant to disease	High	3.72	1.03	4218.48	4.02	0.000	0.120 [0.062, 0.179]	0.121
		Low	3.60	0.96					
	4. Improving nutritional value of livestock	High	3.46	1.12	4118.04	0.92	0.356	0.029 [− 0.033, 0.091]	0.028
		Low	3.43	0.98					
	5. Improving the taste of livestock	High	3.50	1.12	4141.29	1.60	0.110	0.051 [− 0.012, 0.114]	0.048
		Low	3.45	1.00					
V	1. Increasing size of vegetables by 20% (increase by a factor of 1.2)	High	3.26	1.10	4123.92	4.26	0.000	0.133 [0.072, 0.194]	0.129
		Low	3.13	0.97					
	2. Increasing size of vegetables by 50% (increase by a factor of 1.5)	High	3.07	1.14	4099.44	2.85	0.004	0.091 [0.028, 0.154]	0.086
		Low	2.98	0.99					
	3. Making vegetables more resistant to disease	High	3.81	1.01	4240.20	5.90	0.000	0.172 [0.115, 0.229]	0.178
		Low	3.64	0.94					
	4. Improving the nutritional value of vegetables	High	3.75	1.01	4198.22	3.09	0.002	0.094 [0.034, 0.153]	0.093
		Low	3.66	0.96					
	5. Improving the taste of vegetables	High	3.70	1.08	4147.82	2.59	0.010	0.079 [0.019, 0.140]	0.078
		Low	3.62	0.96					

Sample size for each group: $n=2051$ (higher science literacy group), $n=2463$ (lower science literacy group)

have more negative concerns regarding the application of gene-editing technology to food in the cases of livestock than vegetables, especially regarding size enlargement. Such results could imply that our assumption was valid in that, when the target of gene editing was livestock or vegetables, the former would have a higher emotional hurdle than the latter.

The approach of experimental split-ballot design by contrasting two groups of animal-illustrated and plant-illustrated explanations conducted under the above assumption revealed that public attitudes towards food may change due to just one piece of information provision. The respondents who were shown tomato illustrations during the explanation of genome technologies had lower benefits or a stronger tendency for rejection towards gene-edited livestock than did the respondents who were shown pig illustrations. This result may be interpreted using the contrast effect proposed by Sherif et al. (1958), where the first stimulus has a relatively low emotional hurdle, and it provokes a stronger attitudinal response to the second stimulus with a higher emotional hurdle. In this study, the illustrations of pigs (higher hurdle) or tomatoes (lower hurdle) could be interpreted as the first stimulus, and the questionnaire items of gene-edited livestock (higher hurdle) or gene-edited vegetables (lower hurdle) could be interpreted as the second stimulus.

Even when the attitudinal differences due to variations in information provision were statistically significant, the effect sizes of Cohen's *d* were small for general criteria (Cohen 1977). A previous study investigated people's attitudinal differences for the food application of the three technologies of conventional breeding, genetic modification, and gene editing (Kato-Nitta et al. 2019). This research might be practically helpful in the interpretation of the results of this study. Their results revealed approximately 0.1 point mean differences in public attitudes towards gene-edited crops and GM crops by utilising a 5-point scale. The degree of attitudinal differences due to information provision was almost as large as observed differences in benefit perceptions between GM crops and gene-edited crops. To fully address the practical implications of the effect sizes presented in this study, we need to compare our results with the results from other studies. However, we could not find relevant previous research that exactly matched our study's structure to use as a reference. Thus, we anticipate future studies will utilise a different method of information provision such as more realistic illustrations of pigs and tomatoes or illustrations of different livestock or vegetables. Such an accumulation of empirical results could lead to a real understanding of the practical value of the findings of this study. The differences (effect sizes) observed in this study could serve as reference points for such future studies that examine the mean differences in attitudinal variables caused by information provision.

As for the examination of the influence of science literacy on gene-edited vegetables, the higher science literacy group always scored higher regarding improvements in vegetable breeding. These results were concordant with a previous study examining the effects of general scientific knowledge on people's benefit perceptions towards gene-edited crops (Kato-Nitta et al. 2019). The higher science literacy group scored higher regarding improvement in livestock breeding, but only for making livestock more resistant to disease. The results of the previous study mentioned above also showed that the influence of science literacy on reducing risk perceptions was not valid in the case of emerging technologies such as gene editing. Therefore, in the case of livestock, improvements such as changing its size or nutrition value might be considered risky rather than beneficial by the public. According to a study reviewing major national surveys carried out in Ireland, the Irish public tended to show more positive attitudes towards medical applications of biotechnology than agri-food applications (Morris and Adley 2001). Their results may add another interpretation of this study's results regarding science literacy and item L3 (making livestock resistant to disease). The effects of science literacy were statistically significant to all vegetable items (V1 to V5). This may be because in the case of gene-edited vegetables, improvements in nutritional values as well as an increase in size may also be considered as beneficial by the public, just like by producers or scientists.

The ten dependent variables used in this study such as 'increasing size of livestock by 20%' could mean both livestock itself and meat made from livestock. Hence, they are incapable of differentiating between those two kinds of concept. Thus, further studies should investigate this issue by developing items capable of distinguishing those two concepts. In addition, as we utilised a web survey with a non-probability sample, we must be cautious as it is not free from a self-selection bias. The external validity was not secured in this sense, even though sample allocation was made to mitigate the coverage error in the demographics. For overcoming the above limitations of this study and for further generalisation of the results, the following measures could be proposed as future suggestions:

1. Using a sampling frame which is not an online-opt-in panel, but which secures the representativeness of the population.
2. Using a different method for measurement for the dependent variables.
3. Utilising illustrations of livestock or vegetables other than pigs or tomatoes.
4. Conducting the same survey multiple times or conducting the same survey in different countries.

Our approach using the experimental split-ballot design based on a web-survey with randomisation principle was valid in terms of quantitatively examining public perceptions of the role of innovation in food production, as it allows valid reasoning utilising the adequate manipulation of experimental variables. The results of this study provided valuable information for the agri-food community as they help us gain insights into how information provision affects the response of consumers. The results of this study revealed that the public attitude may change due to just one piece of information provided. Experts, including food producers and researchers in related fields, must be aware and pay attention to the impact of informational context, before disseminating their information. It can also be used to provide useful information to the public so that people would understand how our perceptions are influenced by the provision of information. In other words, it might increase the 'literacy' of the public in the broader sense, including that of scientists outside the domain-specific field of genome research.

Appendix 1

This paper includes some technical terms specialised in quantitative survey methodology. The terms are described below.

- Opt-in panel

  Survey respondent group consisting of voluntary registrants operated by a survey company.
- Quasi-representative sample
  The representative sample is drawn from the population by some procedures of probability sampling from a sampling frame that adequately covers the population. On the other hand, using opt-in panel as a sampling frame in a survey does not guarantee such representativeness, since the frame itself does not necessarily represent the population properly

because of its inherent nature of volunteered registrants. To mitigate possible bias, measures are taken to make sample allocation proportionate to population distribution for some demographics. The sample obtained via this operation is often called a quasi-representative sample. See also sample allocation.

- Initial screening
  For collecting quasi-representative sample, initial screening that precedes the main body of the survey usually identifies and allocates the target conditions, such as region, gender, and age.
- Sample allocation
  In a web survey, proportionate sample allocation is often made with regard to the combination of a few demographic variables to approximate the demographic distribution of the target population. In the current study, demographic groups were allocated to a total of 470 groups according to gender, age, and place of residence. The 470 groups are based on the following numbers of the groups: 5 age groups (20–29, 30–39, 40–49, 50–59, and 60–69), 2 genders (male and female), and 47 regions (number of prefectures in Japan). This kind of allocation or its variations are the general operation when using an opt-in-panel administrated by a survey company.
- Recruitment of the sample on first-come first-serve basis
  In this study, survey respondents, who first received a solicitation email, were recruited from panel members that were about ten times the required sample size, considering the population ratio of gender, age, and region (47 prefectures). The respondents were selected on a first-come-first-serve basis until the number matched the allocated sample size. This type of first-come-first-serve principle is also a common practice in web-based surveys using an opt-in panel.
- Directed Questions Scale, DQS
  DQS (Maniaci and Rogge 2014) is an item instructed by a researcher to select a specific response option regardless of whether the answer really applies to the respondents or not. It is used to judge if the respondent has adequately examined the contents of survey questions, depending on whether the respondent complied with the instruction. In this study, three DQS are provided, and respondents who gave wrong answers to all the three DQS were excluded.
- Split-Ballot Survey
  This is a between-subject-one-factor experimental design with multiple dependent variables often used in social surveys. This study has two groups (conditions), the animal and plant group, and respondents were randomly assigned to one of those two conditions. The treatment of such randomisation enabled us to control both observable and unobservable variables of the respondents. The analytical model generally used for this experimental design is MANOVA (Hotelling's T-Squared test). After confirming a statistically significant result with this test, we conducted post-hoc t-tests that are shown in Table 3.

Appendix 2

Science literacy scale:

1. The center of the Earth is very hot.
2. All radioactivity is man-made.
3. The oxygen we breathe comes from plants.
4. It is the mother's genes that decide whether the baby is a boy or a girl
5. Lasers work by focusing sound waves.
6. Electrons are smaller than atoms.
7. Antibiotics kill viruses as well as bacteria.
8. The continents on which we live have been moving for millions of years and will.
9. Human beings, as we know them today, developed from earlier species of animals.
10. The earliest humans lived at the same time as the dinosaurs.
11. Radioactive milk can be made safe by boiling it.

In the survey, the presentation order of the above 11 items were randomised to avoid order effects. Some of the items in this scale may be ambiguous for experts in some disciplines; however, the scale was developed to measure science literacy for the general public and has been repeatedly and internationally used in previous studies. See Sjøberg (2015).

Note

For the group mean comparison, the multivariate analysis of covariance (MANCOVA) is an alternative analysis. However, we chose the MANOVA in this study for the following reasons: the survey respondents were randomly assigned into two groups; thus, the covariate distributions of both the animal and plant groups were almost identical. In such cases, we do not need to adjust the means of dependent variables for the differences in distributions of covariates (science literacy) among the two groups. In this study, the difference in the means of the dependent variable among the two groups adjusted by MANCOVA did not essentially differ from the difference in the unadjusted means. We also conducted a MANCOVA for a robustness check, utilising science literacy as a continuous variable, but found essentially the same result as MANOVA that are presented in this paper.

Abbreviations
GM: Genetically modified; JSPS: Japan Society for the Promotion of Science; CRISPR: Clustered regularly interspaced short palindromic repeats; MANOVA: Multivariate analysis of variance; MANCOVA: Multivariate analysis of covariance.

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Authors' contributions
NKN designed the current research, designed and organised the experimental questionnaire survey, conducted the statistical analyses, and wrote the paper; YI and TM designed the experimental questionnaire survey; MT organised the research project. All authors read and approved the final manuscript.

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Availability of data and materials
Some part of the data in this study was used in previous study (Tachikawa et al. 2019). The datasets generated and/or analysed during the current study are not publicly available due to the regulation from Japanese privacy protection law, but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This survey was conducted under Japanese Privacy Information Protection Law and was approved by the Institute of Statistical Mathematics Ethical Review Board beforehand (No. R17-06). Participation was completely voluntary, and participants could withdraw at any time. Informed consent of all participants was obtained by the survey company.

Consent for publication
All authors reviewed the paper and consented for publication.

Competing interests
The authors declare that they have no competing interests.

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