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EDITED BY
Lenore Lauri Newman,
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REVIEWED BY
Lisa Powell,
Sweet Briar College, United States
Ian Jenson,
University of Tasmania, Australia

*CORRESPONDENCE
Aiko Hibino
✉ ahibino@hirosaki-u.ac.jp

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How can the unnaturalness of cellular agricultural products be familiarized?: Modeling public attitudes toward cultured meats in Japan

Aiko Hibino[1]*, Futoshi Nakamura[2], Mai Furuhashi[2,3] and Shoji Takeuchi[3,4]

[1]Faculty of Humanities and Social Sciences, Hirosaki University, Hirosaki, Japan, [2]Global Innovation Center, Nissin Foods Holdings Co., Ltd., Tokyo, Japan, [3]Institute of Industrial Science, The University of Tokyo, Tokyo, Japan, [4]Graduate School of Information Science and Technology, The University of Tokyo, Tokyo, Japan

Introduction: This study aims to clarify how the unnaturalness of cellular agricultural products can be familiarized to society, using the case of the Japanese public's receptivity to cultured meats. Perceived unnaturalness is a key factor in the rejection of emerging technologies. While past studies have examined the explanatory factors involved in the public acceptance of cultured meats, the relationships among multiple factors have not been fully examined. Cultured meats and cellular agricultural products have been positively evaluated because they can contribute to future food sustainability, so the trade-off between perceived unnaturalness and sustainability is a significant issue for the public.

Method: This study uses a questionnaire survey with 2,000 Japanese respondents, which was conducted in 2019. Using a categorical data analysis approach, the strongest explanatory factors for receptivity were comprehensively searched among attitudes toward cultured meats, eating habits, demographics, and so on.

Results and discussion: The results indicated that perceived unnaturalness showed a strong explanatory power for the rejection of cultured meats, but awareness of world famine problems increased acceptance of cultured meat, if the degree of the respondents' concern for unnaturalness was moderate. The perceived animacy of non-human life forms is also associated with acceptance of cultured meat, which may reflect Japanese cultural values. These results suggest multiple pathways to overcoming the disgust of new food technologies in the social implementation process.

KEYWORDS

perceived unnaturalness, categorical data analysis, animacy, Japan, cultural implications, emerging technologies, cultured meat

1. Introduction

Cellular agriculture is expected to provide an innovative food production system and alleviate the ethical and environmental issues associated with the current ones. New food products derived through technology, such as genetically modified foods, evoke controversy in their emerging phases. The societal and cultural implications of biotechnologies through various frameworks and controversies have been explored in Western cultures (Durant et al., 1998; Bauer and Gaskell, 2002; Wagner et al., 2002; Gaskell and Bauer, 2006; Einsiedel, 2009). The process of accepting cellular agricultural products seems somewhat similar to

that of accepting previous food biotechnologies. Indeed, public discussion of emerging cultured meats tends toward the established metaphor and analogy frameworks concerning genetically modified foods (Marcu et al., 2015; Mohorčich and Reese, 2019). However, whether cellular agricultural technology has sociological and ethical concerns owing to its particular technological features should be carefully considered. For example, the general process for cultured meat does not include animal slaughter; a small piece of muscle is taken from a cow, pig, or chicken, and isolated muscle cells are grown into larger quantities *in vitro*. Subsequently, proliferating cells differentiate into muscle fibers in appropriate culture media and eventually grow into muscle tissue. The manufacturing of cultured meat avoids ethical problems by avoiding animal slaughter and genetic modifications.

Contextualizing the technological uniqueness of cellular agricultural technology in our sociotechnical society still requires further examination (Stephens and Lewis, 2017; Stephens et al., 2018; Treich, 2021). While cellular agricultural technology is expected to help solve the environmental need to reduce CO_2 emissions from livestock (Sexton et al., 2019; Tomiyama et al., 2020), scientific and technical solutions to sustainability problems may face acceptance issues in the public if they require excessive adaptation of existing culturally shaped habits and preferences. A sustainable society will be enacted if cultural (local) habits and preferences are adequately considered in the new sociotechnical system. In addition, it is important to consider the public's understanding of cultured meats, as there may be opportunities to build multiple frameworks for societal and ethical issues that are triggered by novel technologies (Driessen and Korthals, 2012; Bauer and Bogner, 2020). We focus on the case of cultured meat among the various application of cellular agriculture and discuss its social implementation, as it has been at the center of public and policy debate (Jönsson, 2016; O'Riordan et al., 2017).

2. Background

2.1. Public acceptance of cultured meats

Over the past few years, many social science studies have been conducted regarding the public acceptance of cultured meats. Bryant and Barnett (2018) provide a comprehensive systematic review of 14 peer-reviewed studies on consumer acceptance of cultured meats, summarized by design type, country, sample, and cultured meat type, with the main findings analyzed in detail. Bryant and Barnett's review found that previous studies have focused on the perceived image of unnaturalness (of cultured meats), safety, taste, and prices. An updated review (Bryant and Barnett, 2020) summarized 26 studies on the public perception of cultured meats, indicating that most of the public would like to try cultured meat in many countries. A systematic review by Pakseresht et al. (2022) showed that public awareness, perceived naturalness, and food-related risk perception are the important factors influencing consumer acceptance of cultured meats. As described in these reviews, previous studies have clarified several factors of consumer acceptance of cultured meats, and some have proposed predictive models (Wilks et al., 2019; Siegrist and Hartmann, 2020b). Perceived naturalness has often been examined among various important factors, as described in the following paragraph.

Notably, perceived unnaturalness is the most common objection to cultured meat among the factors studied (Siegrist and Sütterlin, 2017; Bryant and Barnett, 2018; Wilks et al., 2021), and unnaturalness is generally indicated as a critical factor to public understanding of life science technologies (Aizaki et al., 2011; Marcu et al., 2015). Concerns about whether something is "unnatural" underpins the rejection of other food technologies, such as artificial additives, chemicals (Roman et al., 2017), and novel food technologies (Siegrist and Hartmann, 2020a). Wilks et al. (2021) explored the meaning of unnaturalness in the public opinion of cultured meats and concluded that the perception of unnaturalness came from factors such as disgust and fear, rather than rational reasoning. In addition to unnaturalness, safety, healthiness, anticipated taste, and anticipated price were other personal concerns regarding cultured meats.

Some studies have examined consumer acceptance of cultured meat and its associated factors within a national context, such as Italy (Mancini and Antonioli, 2019), Germany (Dupont and Fiebelkorn, 2020), and Belgium (Bryant and Sanctorum, 2021); intercultural differences have also been explored (Bekker et al., 2017; Gasteratos and Sherman, 2018; Bryant et al., 2019; Gómez-Luciano et al., 2019; Siegrist and Hartmann, 2020b). Notably, demographic and attitudinal factors associated with the acceptance of cultured meats vary according to each country's local context. For example, international comparisons in countries including the USA, China, and India, found that public acceptance of cultured meat was affected by the perceived image of healthiness and safety in China, whereas the perception of ethical issues was critical in India (Bryant et al., 2019). Few survey studies have examined attitudes toward cultured meats in Asian countries, except for studies in China (Bryant et al., 2019; Zhang et al., 2020). A limitation of previous research is that many studies have not fully considered relationships among multiple factors in the explanatory variables; thus, the relative impact of perceived naturalness is unclear. In addition, questionnaire surveys have not fully clarified the images of cultured meats in a cultural context and how they affect people's acceptance.

What is interesting here is how a specific new food technology that emerges with a schema of seemingly positive values interact in the cultural context. This study partly relies on the social representation theory (Moscovici, 1984)—a major meta-theory focusing on the societal process in social psychology—as an analytical framework. Social representation theory provides a framework for understanding the societal process of new technologies in which the unfamiliar are familiarized. *Anchoring* and *objectification* are critical processes in the social representation theory. In anchoring, unknown objects are processed according to the existing semantic systems and customs, and in objectification, they become a reality through institutionalization in the process of materialization. While the framing of a "contribution to the sustainable society" has dominated discussions around cultured meats, it is questionable whether such framing would be adapted, as it was in the anchoring process. The factors associated with public acceptance of cultured meats differ across countries, as mentioned above, and can be reinterpreted using social representation theory in terms of how framing, rooted in the cultural context,

emerges in the public understanding of cultured meats in a specific country.

Studies using approaches other than questionnaire surveys also provide useful perspectives on the familiarization process of cultured meat. Sexton et al. (2019) examined the typology of the narrative pros and cons of alternative proteins, and clarified the tensions among them. Bogueva and Marinova (2020) examined the attitudes of the younger generation, and Ruzgys and Pickering (2020) examined how messaging strategies affect the younger generation's acceptance of cultured meat. Recently, the impact of framing (Bryant and Dillard, 2019) and labeling (Bryant and Barnett, 2019) cultured meats has been considered from a practical viewpoint using empirical surveys. In addition to these questionnaire surveys, the power of metaphors concerning cultured meats (Broad, 2020), narratives in media coverage (Painter et al., 2020), and key meanings and their transitions (Stephens et al., 2019) have been examined.

2.2. Japanese context

Although cultured meat has not yet been approved in Japan, research and development of these technologies has been active since 2020. Recently, there has been intensive research and development on cultured meat at the University of Tokyo, mostly in tissue engineering. A prominent feature of this group is the research on the production of "real meat" products. While there has been much research worldwide for developing technologies to culture meat in a minced state, the University of Tokyo group and its collaborators have focused on meat in the structured state. The major characteristic of structured meat is that it is thick, with a chewy texture similar to that of steak. The Tokyo group focuses on aligning muscle fibers and building a thick three-dimensional structure that is closer to the meat from slaughtered animals.

There has been much research on Japanese public perceptions of genetically modified foods, clone technologies, and synthetic biology (Hibino, 2010; Aizaki et al., 2011; Hibino et al., 2019), but there have been no surveys on attitudes toward cultured meats. The acceptance of genetically modified foods in Japan have been as low as that of European countries since the early 2000s (Hibino, 2010). It is also concerning that the Japanese public's awareness regarding the concept of "ethical" (as a specific translation of a prefix in the Japanese marketing context) (8.8%) and "ethical consumption" (12.2%) were found to be relatively low in 2019 (Japanese Consumer Affairs Agency, 2020). This is in line with the low awareness of the concept of fair trade, as only 23.2% of respondents had heard of it in Japan (Japanese Consumer Affairs Agency, 2020). This percentage is extremely low compared to Europe, where over 80% of people were reported to be familiar with fair trade (Globescan, 2015). We can see that there is little awareness of new food technology in Japanese society, and that Japanese people are expected to be relatively cautious about accepting cultured meat.

While public attitudes toward the pros and cons of biotechnology are similar in Japan and Europe, there is a possibility that a culturally specific framework for life may be associated with public receptibility of life science products, including cultured meats. Japanese philosophical studies suggest that *life* as a concept including the fate (*karma*) of exchanging lives and the "emotions" that arise in the Japanese context; this contradicts the concept of life emphasizing individuality, primarily present in the Western culture (Sagara, 1994; Kimura, 2002; Takeuchi, 2011). Empirical analysis of media discourses in Japan showed that Japanese people have a unique frame of reference, in that they have an emotional attachment to cloned animals (Hibino and Nagata, 2006). In summary, in the Japanese context, it has been suggested that the understanding of *life* is on a continuum between living and non-living things. This way of understanding, in association with the Japanese receptivity of cultured meats, should be further investigated.

This study aims to clarify how the unnaturalness of cellular agricultural products can be familiarized to society, using the case of the Japanese public's receptivity to cultured meats. First, we aim to explore the factors determining public receptivity to cultured meat by focusing on the role of the perceived unnaturalness of cultured meat, while also considering relationships among multiple factors. Second, this study aims to clarify how the perception of animacy of non-human living things, which is salient in the Japanese view of nature, affects the public's receptivity to cultured meat. Past qualitative and quantitative studies on the public's acceptance of emerging technologies have indicated the critical role of cognition in unnaturalness. Our analysis will contribute to studies on the acceptance of cultured meats by exploring relationships between factors and their semantic meaning in a local context, which might address the issue of how contradictive perspectives can be coordinated when the feeling of disgust and globally supported evaluations of cultured meat are actualized in the public sphere. The study also addresses the pathway for managing unnaturalness based on a cultural context.

3. Materials and methods

3.1. Survey overview

A survey was conducted online among 2,000 Japanese respondents aged 20–59 years (male respondents = 1,000; female respondents = 1,000), randomly selected by a Japanese survey research company (Cross Marketing) from panels in May 2019. Cross Marketing is one of the established research companies that have experience in academic social surveys, and it has five million panels recruited on various internet media. The participants of our survey were randomly selected from these panels. After being provided with the outline of questions and information about the purposes of this study, they were asked to agree to respond to the survey. There was an incentive for participants, as those who completed the survey were awarded electronic points that could be used for purchases. The participants were equally distributed by sex and age (eight groups). The survey represented Japanese people in this age range. To maintain the quality of the answers in the web survey, the questionnaire included a trap question and eliminated respondents who did not answer the questions seriously. The research company periodically carries out duplicate checks to eliminate illegally registered panels, which also helped to maintain the quality of the answers.

Before they survey was conducted, the Research Ethics Committee of the Faculty of Humanities and Social Sciences, Hirosaki University, reviewed all the study materials and approved the study (No. 2019-01).

Considering that this study aimed to explore the factors that were most strongly associated with receptivity to cultured meats, a questionnaire was designed to cover the main items that may have been previously investigated. The major components of the questionnaire were the perception of cultured meats, willingness to eat, attitudes toward cultured meats, perceived animacy of non-human life forms, perceived naturalness of new technologies, eating habits, demographic information of sex, age, educational background, and so on (see Supplementary Table I).

First, participants were asked about their perception of "cultured meats," and they could also provide free-form responses about their perceptions of "meat" and "life." Participants answered before they were provided with a description of the cultured meat. In Japan, information on cultured meats was receiving hardly any media coverage when we conducted the survey in 2019, and a simple description of the production method for cultured meat was provided in the survey. The description was technically correct but also simple and minimal so that participants' judgments of cultured meats would not be influenced: *Cultured meat is made by isolating cells from the muscle of an animal (cattle, etc.) and culturing several cells to produce an edible piece of meat. This technology does not clone an animal; instead, it cultures tissue using cells obtained from an animal's tissue.* Our questionnaire adopted the term *baiyo-niku* in Japanese as the literal translation of cultured meat, as it was widely used in 2019. While the survey included comprehensive questions, we discussed the following three areas:

1. Willingness to try cultured meat: This study asked respondents, "Would you be willing to try cultured meat?" (five categories: "definitely no = 1"; "probably no = 2"; "unsure = 3"; "probably yes = 4"; and "definitely yes = 5"). The question of willingness to engage is common in other surveys (Wilks and Phillips, 2017).

2. Agreement with statements about attitudes toward cultured meats: "CM is unnatural," "CM is disrespectful to nature," "CM is ethical," "CM will improve animal welfare conditions," "CM will be able to solve world famine problems," "In the future, CM will be a viable alternative to farmed meat," "CM will have negative impacts on traditional farmers" (five categories: "strongly agree = 1"; "agree = 2"; "unsure = 3," "disagree = 4"; "strongly disagree = 5"). This question is common in other surveys (Wilks and Phillips, 2017).

3. Cognitive image of life: This study asked respondents, "Which items do you think are alive?" and provided multiple choices ("cells," "bacteria," "animals," "viruses," "DNA," and "atoms"). The total number of chosen items was used as an index for the broadness of the cognitive image of life (from 0 to 6).

Data were analyzed using both the R version 4.0.0 and SPSS version 27. The relationships between items were examined and supported by categorical data analysis using the Akaike Information Criterion (AIC) (Katsura and Sakamoto, 1980; Sakamoto, 1992).

3.2. Basic statistics

The basic statistic of the dependency for the distribution of a specified variable (response variable) on other variables (explanatory variables) was derived and evaluated using the AIC (Sakamoto and Akaike, 1978; Sakamoto, 1992; The Institute of Statistical Mathematics, 2020). The AIC, which is one of the commonly used criteria for statistical model selection, utilizes the maximum likelihood principle. The methodological advantages of categorical data analysis are as follows: First, this program can explore reliable variables by automatically analyzing all their combinations of through an exhaustive search for a condition (Seichi et al., 2012; Takahashi et al., 2019). This enables the modeling of public attitudes toward cultured meats without a specific assumption. Second, this program clarifies the proper division pattern of ordinal scales in explanatory variables. Third, this is useful for detecting factors that have a nonlinear relationship with target valuables.

We used the following statistics to measure the strength of the dependence of a specific set of response variables on the explanatory variable, as defined by Sakamoto (1992). The Institute of Statistical Mathematics (2020, p. 7) explained this statistic as follows:

> E denotes the response variable and F denotes candidate explanatory variable, and their cell frequencies by $n_E(i)(i \in E)$ and $n_F(j)(j \in F)$. The cross frequency is denoted by $n_{E,F}(i,j)(i \in E, j \in F)$. To measure the strength of dependence of a specific set of response variables E on the explanatory variable F, we use the following statistic:

$$AIC(E;F) = -2 \sum_{i \in E, j \in F} n_{E,F}(i,j) \ln \frac{n_{E,F}(i,j)}{n_F(j)} + 2C_E(C_F - 1), \quad (1)$$

> Where C_E and C_F denote the total number of categories of the corresponding sets of variables, respectively.
>
> The selection of the best subset of explanatory variables is realized by the search for F which gives the minimum $AIC(E;F)$. In case of $F = \phi$, the formula (1) reduces to

$$AIC(E;\phi) = -2 \sum_{i \in E} n_E(i) \ln \frac{n_E(i)}{n} + 2(C_E - 1)$$

> Here it is assumed that $C_\phi = 1$ and $n_\phi(1) = n$.
>
> Sakamoto's original CATDAP (the categorical data analysis program package) outputs $AIC(E;F) - AIC(E;\phi)$ as the AIC value instead of $AIC(E;F)$.

This study also used $AIC(E;F) - AIC(E;\phi)$ as the AIC value. Note that the AIC index from $AIC(E;F)$ is more appropriate when comparing the goodness of fit of the model with other models. The R package of CATDAP-02 provides the base AIC value of

TABLE 1 Socio-demographics and willingness to eat cultured meat ($N = 2{,}000$).

Questions/response options	% of sample
Gender	
Male	50.0
Female	50.0
Age	
20–29	24.8
30–39	24.8
40–49	24.8
50–59	25.6
Education	
Junior high school	3.1
Completed high school	28.2
College/undergraduate/postgraduate degree	68.5
Other	0.4
Have you heard of cultured meat?	
Yes	27.1
No	73.0
Would you be willing to try cultured meat?	
Definitely yes	6.4
Probably yes	21.3
Unsure	28.5
Probably no	24.3
Definitely no	19.5

$AIC(E;\phi)$, which can be used to calculate the AIC index from $AIC\,(E;F)$.

This categorical data analysis was applied to evaluate the dependencies of engagement with cultured meats as a response variable to 40 explanatory variables: attitudes toward cultured meat, perceived animacy of non-human life forms, perceived naturalness of new technologies, eating habits, and demographic information (see the Supplementary Table I). The categorical data analysis program package (CATDAP) for R was developed by the Institute of Statistical Mathematics in Japan (The Institute of Statistical Mathematics, 2020). Data analysis was carried out using CATDAP-02, which searches for the best single explanatory variable and detects the best subset of explanatory variables, as well as the optimal categorization of continuous values.

4. Results

A total of 2,000 responses were obtained. Our sample was equally split between male (50%) and female (50%) respondents. The sociodemographic variables of sex, age, education, and awareness of cultured meats are presented in Table 1. Less than

TABLE 2 Top variables associated with cultured meat engagement (ordered by AIC*).

Top 20 explanatory variables	Number of categories of exp. var.	AIC**
CM is unnatural	5	−523.8
CM is disrespectful to nature	5	−437.1
CM will be a viable alternative to farmed meat	5	−299.9
CM is ethical	5	−231.1
CM will be able to solve world famine problems	5	−219.7
CM will improve animal welfare conditions	5	−165.9
CM production will have negative impacts on traditional farmers	4	−107.8
Interest in fair trade and environmentally friendly foods	5	−104.5
Preference for meat	4	−85.5
Have heard about cultured meats	2	−81.7
Sympathetic to vegetarianism	4	−67.7
Perceive naturalness of vegetables in plant factories (vertical farming)	2	−61.0
Perceive naturalness of genetically modified foods	2	−53.3
Perceive wide spectrum of animacy	3	−43.2
Perceive animacy of bacteria	2	−40.8
Sex	2	−37.8
Frequency of meat eating	4	−36.7
Perceive naturalness of organs from iPS cells	2	−31.1
Perceive naturalness of robots	2	−18.6
Top 5 subsets of explanatory variables	**Number of categories of exp. var.**	**AIC**
CM is unnatural CM will be able to solve world famine problems Have heard about cultured meats	24	−729.5
CM is unnatural CM will be able to solve world famine problems	12	−727.2
CM is unnatural CM will be able to solve world famine problems Age	24	−698.0

(Continued)

TABLE 2 (Continued)

Top 5 subsets of explanatory variables	Number of categories of exp. var.	AIC**
CM is unnatural CM will be able to solve world famine problems Perceive wide spectrum of animacy	24	−695.3
CM is unnatural CM will be able to solve world famine problems Perceive animacy of bacteria	24	−693.4

*AIC, Akaike information criterion.
** Base AIC = 6110.17.

one-third of the respondents had heard of cultured meats, which suggests that awareness was still low in 2019.

4.1. Willingness to try cultured meats

The results showed that 27.7% of respondents answered that they would like to try cultured meats (6.4% = "definitely yes"; 21.3% = "probably yes"). In addition, 28.6% of respondents answered that they were unsure, and 43.8% said they would not like to try it (composed of 24.3% = "probably no"; 19.5% = "definitely no"). This rate shows that Japanese receptivity to cultured meat was relatively low compared to that of other countries. Japanese respondents seemed less likely to try cultured meats; however, they were more positive when asked about its significance. Of the respondents, 54.6% agreed with the statement that "cultured meat will be able to solve world famine problems" ("strongly agree" and "agree"), which is about the same rate as that reported in the US survey (Wilks and Phillips, 2017).

4.2. Model for receptivity to cultured meats

Categorical data analysis was applied to search for variables that strongly affected the response distribution of the objective variable of willingness to engage with cultured meats. Table 2 shows the top 20 variables, where the lower the AIC value, the stronger the explanatory variable in relation to the objective variable. Snare analysis with cross-sectionality was used to search for the variables that indicated the main factors that strongly affected the receptivity to cultured meat, eating habits, perceptions of new technologies, and life forms. The most relevant variable for receptivity to cultured meat was the perception of its unnaturalness (AIC = −523.8, Cramer's V = 0.28). Among the respondents who thought that cultured meat was unnatural (strongly agree), about 76% did not want to try it (Figure 1). Conversely, among respondents who thought that cultured meat was natural, 40% said that they would like to try it and 56% said that they would not like to try it. These results suggest that the recognition of the unnaturalness of cultured meat could be associated with its rejection, whereas the recognition of its naturalness could be associated with both rejection and acceptance. We observed asymmetry in the finding that low eating engagement appeared in negative attitudes, such as ethical and animal welfare conditions. The only exceptions were the items on world famine, where the agreement that cultured meats could directly solve world famine problems was associated with interest in eating it.

An analysis of optimal combinations of two or more explanatory variables by CATDAP-02 showed a combination of perceived naturalness and concern for world famine problems as strongly associated with receptivity to cultured meats (AIC = −727.2) (Table 2). The combination set with the strongest explanatory power was "CM is unnatural," "CM will be able to solve world famine problems," and awareness of cultured meat (AIC = −729.5), which were stronger than the explanatory power of "CM is unnatural" on its own (AIC = −523.8) (see Table 2). The cross table shows that except for those who strongly rejected cultured meat, respondents' willingness to try cultured meat increased with the degree to which they agree that food technology was useful for sustainably food system (Table 3). To confirm the robustness of the modeling suggested by CATDAP-02, ordinal logistic regression was conducted on receptivity to cultured meat as the objective variable, and agreements with "CM is unnatural" and "CM would be able to solve world famine problems" as explanatory variables. Two factors of perceived unnaturalness and concern for the world famine problems explain receptivity to cultured meat (receptivity ~ perceived unnaturalness + concern for the world famine problems; AIC = 5506.6, residual deviance = 5482.6, N = 2,000), which were better than the model with a single factor of perceived unnaturalness (receptivity ~ perceived unnaturalness; AIC = 5714.3, residual deviance = 5760.4, N = 2,000).

Furthermore, opinions related to cultured meat (AIC = −299.9 to −107.8), consumption beliefs (−104.5), the variables of eating habits (AIC = −85.5), and information exposure (AIC = −81.7) show a relatively strong association with the willingness to engage with cultured meats. Regarding opinions related to cultured meats, the more highly people rated the significance of cultured meats, the more likely they were to try it. As a variable related to food preferences, those who liked meat and those with a high affinity for vegetarianism were more interested in sampling cultured meats.

Notably, variables concerning how respondents perceived life forms had a relatively strong association with their willingness to try cultured meat. The larger the number of objects that respondents considered animate, the more likely they were to be willing to try cultured meat. 31.9% of respondents who considered more than four objects as animate were willing to try cultured meat, whereas only 7.5% of respondents who considered no objects as animate expressed this willingness (AIC = −43.2) (Figure 2). The subsets of explanatory variables including spectrum of animacy (AIC = −695.3) and perceived animacy of bacteria (AIC = −693.4) were highly ranked in AIC (Table 2). In short, it can be considered that the receptivity to cultured meat is partly rooted in people's belief in animacy. Willingness to engage with cultured meat was also associated with the perceived naturalness of other currently emerging technologies, such as genetically modified foods, iPS cells, and robotics. Respondents who regarded

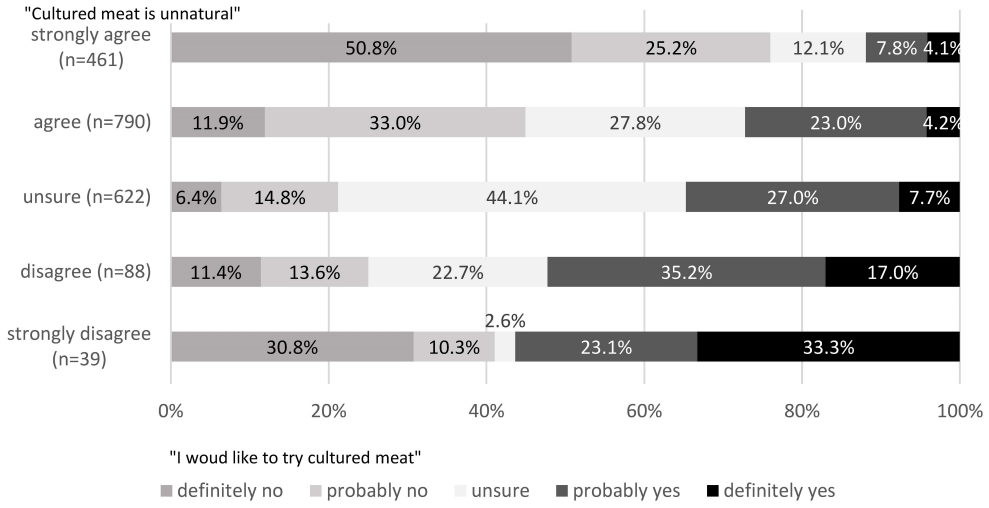

FIGURE 1
Association between agreement with "cultured meat is unnatural" and willingness to try it (AIC = −523.8).

these technologies as natural tended toward a willingness to eat cultured meats. Conversely, the attribute items were less related to an interest in eating cultured meats. The attribute variables (educational background, income, etc.) had a relatively weak effect on sampling interest.

4.3. Perceived image of life, meat, and cultured meat

We used text analysis of the participants' responses (open-ended answers) to interpret their understanding of cultured meats and life forms, as this methodology is useful for analyzing responses to unfamiliar new food technologies (Stoneman et al., 2013; Eisner et al., 2019). A text analysis of the narratives in the open-ended responses support the interpretation that perceptions of cultured meats are involved in accepting its technology in Japan. The free-answer items analyzed in this study were as follows: "What do you think about your life?"; "What do you think about meat?; and "What do you think about cultured meat?" We first extracted the top 40 most frequently occurring words from the respondents' descriptions for each questionnaire item. There was a significant difference in the frequency of word usage between those who were interested in trying cultured meats and those who were not ($p < 0.05$) (see Supplementary Table II).

Japanese respondents' descriptions can be classified into those focusing on individual objects and relational networks in an ecological system according to their receptivity. Those who were affirmative to cultured meats tended to refer to the "food chain" and "cattle (cow)" instead of "beef." The examples of narratives are as follows; *"(Meat is) something those human beings can eat only at the cost of such precious sacrifices as cattle, pig, and chicken." "(Life is) all that is in the circle of the food chain and that cannot escape from it." "In the world of the food chain, it seems inevitable that a strong one will prey on the weak, but I want to respect and utilize the dignity of individual lives as much as possible."* Such descriptions seem to reflect cultural values among the Japanese, rather than simply referring to the natural scientific concept of the food chain system. Conversely, the words that characteristically appeared in the free answers from those who rejected cultured meats were "artificial," "body," and "fear" as images of cultured meat, and "steak" and "beef" as images of meat. This may be because of an emerging framework for cultured meat that has a relational view of life, partly reflecting Japanese cultural values (Sagara, 1994; Kimura, 2002; Takeuchi, 2011). This provides a perspective on accepting cultured meats, even if it is considered an unnatural object.

5. Discussion

This section discusses perceptions of the naturalness of cultured meat, animacy, and how the unnaturalness of cell agricultural products can be familiarized in society.

5.1. Familiarizing unnaturalness with sustainability

Important factors associated with cultured meat engagement include the unnaturalness of cultured meats. Previous research on public understanding of science has examined and discussed the perceived unnaturalness of biotechnology and new food technology, which is one of the key factors leading to technology neophobia (Aizaki et al., 2011; Marcu et al., 2015; Siegrist and Sütterlin, 2017; Bryant and Barnett, 2018; Siegrist and Hartmann, 2020a; Wilks et al., 2021). The present study clarified the explanatory power of unnaturalness using the AIC index, which measures the explanatory value of a specific variable when compared with other variables for cross-sectional analysis.

The results showed a non-linear association between perceived naturalness and receptivity; cognition of the unnaturalness of

TABLE 3 Contingency table constructed using the subset of explanatory variables for agreement with "would like to try cultured meat" (AIC = −727.2).

		Definitely no	Probably no	Unsure	Probably yes	Definitely yes	Sum	N
Agreement with "CM is unnatural" (X2)	Agreement with "CM will be able to solve world famine problems" (X3)							
1	1	55.6	0.0	5.6	22.2	16.7	100.0	18
1	2	10.0	30.0	0	20.0	40.0	100.0	10
1	3	9.1	9.1	0	27.3	54.5	100.0	11
2	1	10.5	17.8	47.3	19.0	5.4	100.0	427
2	2	2.0	12.4	37.8	39.3	8.5	100.0	201
2	3	1.2	3.7	19.5	47.6	28.0	100.0	82
3	1	20.1	38.2	29.3	11.2	1.2	100.0	259
3	2	8.8	33.7	29.5	26.0	2.0	100.0	407
3	3	4.8	20.2	19.4	37.9	17.7	100.0	124
4	1	62.4	22.9	9.3	3.4	2.0	100.0	205
4	2	41.3	34.2	14.2	7.1	3.2	100.0	155
4	3	41.6	15.8	14.9	17.8	9.9	100.0	101
Total		19.5	24.2	28.6	21.3	6.4	100.0	2,000

The CATDAP-02 searched for the optimal categorization of the continuous values, and the results were as follows: in X2, 1 = "strongly disagree," 2 = "disagree" and "unsure," 3 = "agree," and 4 = "strongly agree," and in X3, 1 = "strongly disagree," "disagree," and "unsure"; 2 = "agree"; and 3 = "strongly agree." The values with a gray background (rows 2–4 in X2) are more than 10 points higher than the percentages of the total distribution.

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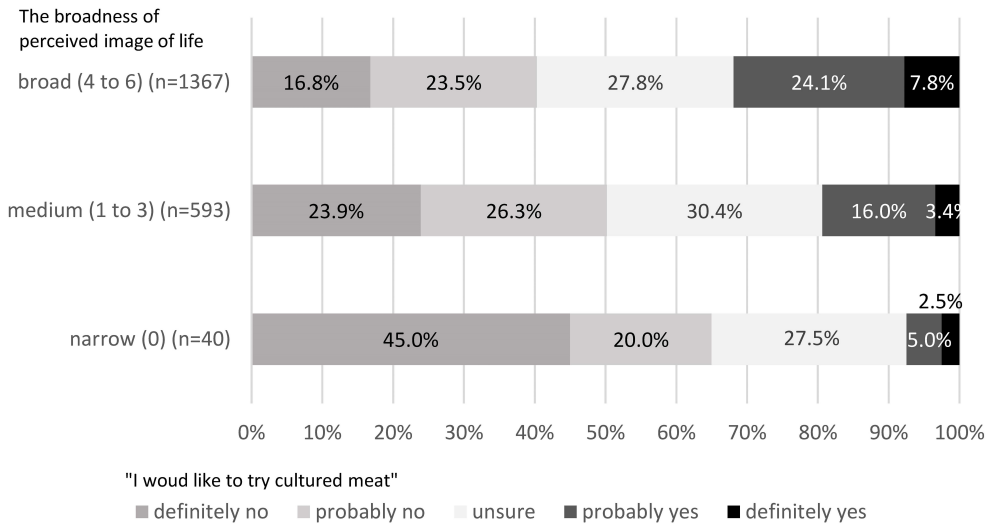

FIGURE 2
Association between number of objects perceived as animate and willingness to try cultured meat (AIC = −43.2).

cultured meat was associated with an unwillingness to try it. On the contrary, the cognition of naturalness is related to both willingness and unwillingness. Why are perceived unnaturalness and naturalness asymmetrical? Is it difficult to improve public acceptance of cultured meats by emphasizing the naturalness of technologies? The critical point may lie in the fact that people might use the term "unnatural" as an expression of aversion. Here, it is synonymous with "I don't want to eat it," and it is conceivable that the two constitute the same feeling, which is grounded in affective mechanisms such as disgust, fear (Wilks et al., 2021), and distrust (Marcu et al., 2015). Conversely, "nature" was mobilized by respondents as the usefulness of cultured meat to "the natural environment and ecosystem." A study of lay and expert arguments regarding "naturalness" (Ditlevsen et al., 2020) found that laypeople see synthetic vaccines as unnatural, suggesting a connection between risk evaluation and objects.

Moreover, it is considered that the plural meanings of "naturalness" affects polarized receptivity. Of the respondents, 16.3% answered that they thought cultured meats respected nature, which was higher than those who said it was "natural" (6.4%). A significant percentage of respondents think that cultured meat itself is unnatural but that it respects "nature." Among the respondents who gave such answers, their logic may be that cultured meat is *not natural* because it is an artificial product. However, when it comes to nature as a global ecosystem, cultured meat can *contribute to nature*, although this interpretation is limited to the Japanese context.

Although naturalness was the most important factor for public receptivity to cultured meats, we should note that other factors, such as the possibility of solving world famine problems and improving animal welfare, were highly ranked in the AIC. An agreement to solve famine is an especially important factor in the discussion of cultured meats, as there was a linear relationship between this variable and acceptance. In addition, this variable showed the strongest explanatory power in combination with the perception of naturalness. In other words, it may suggest that the rejection of cultured meat is associated with perceived unnaturalness, whereas its acceptance comes from recognizing the social significance of environmental issues. Policymakers can utilize a global food system framework with environmental issues to contextualize cultured meats, although implicit faith in food productivism should be unpacked carefully (Iles et al., 2016).

5.2. The role of cultural value: The perceived animacy of non-human lifeforms among the Japanese

What is interesting from our analysis is that the Japanese public's willingness to eat cultured meat is strongly associated with how they perceive non-human life forms. Those who perceive animacy in non-human life forms are also willing to try cultured meat. This result might seem strange to those who think that people should avoid eating all lifeforms and can be interpreted as follows. It is significant that the tolerance of ambiguity (Furnham and Marks, 2013) of artifacts is critical to the formation of public acceptance of cultured meat in the Japanese context. In other words, how people organize semantic classifications among objects, which includes boundary entities, affects their evaluation of cultured meats. There are those who view clear distinctions between animated and unanimated objects, and they might have negative perceptions of cultured meats because the boundary entity between natural and unnatural, or between living and non-living things, does not have a position in their meaning system. In contrast, those who view a continuum between animated and unanimated objects have a positive perception of cultured meats. This is because a new entity can have any meaning for those with such continuous views, even if it includes ambiguity. As described before, in Japan, the concept

of life forms a continuum with non-living things and includes the fate of exchanging life and the "emotions" (Sagara, 1994; Kimura, 2002; Takeuchi, 2011). The results of the present study significantly reflect the uniqueness of Japanese culture. A previous survey on public perception of genome-editing techniques and synthetic biology provided similar findings: the depth of understanding of the perceived body image, including components other than the physical body, led to a positive evaluation of emerging life science technologies (Hibino et al., 2019).

The impact of social attributes such as education, income, and occupation, as noted in several previous surveys, were found to be relatively small. This study also found an association between age and sex; however, it suggested that the effect was small when compared with other items. Similar results have been found in previous Japanese surveys. In recent years, the preference for advanced technologies has not been determined by the evaluation systems of social classes or groups, but rather by the feeling of objects rooted in body perception.

5.3. How to cope with the unnaturalness of new food technologies

Studies on public perception of cultured meats have clarified the critical role of perceived unnaturalness in attitude formation, which has been well discussed in previous studies on emerging food technologies. The implications of this study in the Japanese context are as follows: First, it is considered that the framework of social significance and environmental sustainability, in this case, could assist in the discussion and decision-making process for the social implementation of cultured meats, although the perceived unnaturalness of emerging food technologies is strongly associated with public rejection, and such a feeling could not be easily dissolved. Considering that the public receptivity of cultured meat is strongly affected by the configuration of perceived naturalness and world famine problems, it is *inadequate* to appeal directly to the public regarding the "naturalness" of emerging technology to increase its acceptance. As Wilks et al. (2021) discussed, although the perception of "unnaturalness" influences the rejection of cultured meats, it does not mean that the concept of "naturalness" is an antidote to acceptance problems. Marcu et al. (2015) clarified the importance of dialogue; for instance, it is important to promote questions concerning any proposed facts or refer to the management aspect of a new production system. The possibility of discussing emerging technologies seems to expand perspectives, and not simply the literacy improvement of laypeople.

Second, the findings of this study indicate that important factors unique to a specific country emerge in the early phase; such an understanding that is based on cultural frameworks can possibly overcome the dichotomy between the naturalness and unnaturalness of emerging food technologies. For Japanese people, the salient logic of Japanese respondents that focuses on the interrelationships between living things is strongly associated with the acceptance of cultured meats. Interestingly, the perceived animacy of non-human lifeforms are associated with acceptance, although this local framework can also be associated with public rejection. Its *interdependency* addresses the acceptance of new and artificial food technologies, providing another pathway for discussion. What should be noted here is that when evaluating emerging technologies, it is important to have a dynamic perspective wherein the culturally unique framework provides a system of meaning for unfamiliar objects, and the framework itself can be changed gradually.

5.4. Conclusion

This study aims to clarify how the unnaturalness of cellular agricultural products can be familiarized with society, taking the case of the Japanese public's receptivity to cultured meats. It clarified that the perception of unnaturalness showed strong explanatory power for rejection of cultured meats. Furthermore, it showed that the configuration of the explanatory factors of attitudes, eating habits, and perception of non-human life forms played a critical role in the receptivity to eating cultured meats. The important results of our study show the empirical strength of the numerical AIC index with cross tables. One problem to consider is that our findings were derived from the case of cultured meat, so the broad issues in cellular agricultural products should be examined in future research. The study also examined culturally specific framework for life in Japanese, which also relates to the ethical perspective of cellular agriculture; hopefully, this will be verified in international comparative studies in other cultural contexts, including Asia. This multi-layered approach can be seen in public awareness, and is necessary when examining a reasonable response to it in policy discussions and communications.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Committee of the Faculty of Humanities and Social Sciences, Hirosaki University. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

AH, FN, MF, and ST conceived and designed the study and acquired the data. AH analyzed the data and drafted the manuscript. FN, MF, and ST substantially revised the manuscript. All authors made a substantial contribution toward the development of the final manuscript and approved its publication.

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Conflict of interest

FN and MF are employed by Nissin Foods Holdings.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2023.1129868/full#supplementary-material

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