frontiers | Frontiers in Sustainability

TYPE Community Case Study
PUBLISHED 08 September 2022
DOI 10.3389/frsus.2022.927857

OPEN ACCESS

EDITED BY
Diana Gregory-Smith,
Newcastle University, United Kingdom

REVIEWED BY
Panayiota Alevizou,
The University of Sheffield,
United Kingdom
Jennifer TyreeHageman,
University of Birmingham,
United Kingdom

*CORRESPONDENCE
Yurina Otaki
yurina.otaki@r.hit-u.ac.jp

SPECIALTY SECTION
This article was submitted to Sustainable Consumption, a section of the journal Frontiers in Sustainability

RECEIVED 25 April 2022
ACCEPTED 03 August 2022
PUBLISHED 08 September 2022

CITATION
Otaki Y and Kyono T (2022) Effects of information provision on public attitudes toward bioplastics in Japan. *Front. Sustain.* 3:927857. doi: 10.3389/frsus.2022.927857

Effects of information provision on public attitudes toward bioplastics in Japan

Yurina Otaki* and Taisei Kyono

Graduate School of Social Science, Hitotsubashi University, Kunitachi, Japan

Bioplastics (i.e., bio-based and biodegradable plastics) are attracting attention as a sustainable alternative to conventional fossil-based plastics. However, their use in Japan, the fifth-highest per capita disposal of single-use plastics, has not become as widespread as planned by the Japanese government, and an increase in consumer awareness is necessary to promote the use of bioplastics and increase the demand for sustainable products. In addition, to promote social implementation, it is also necessary to understand the difference between bio-based and biodegradable plastics and use them correctly. Through an online questionnaire survey, this study found that the Japanese public's knowledge of bioplastics was low: there was a major difference between subjective and objective knowledge, but their perception of bioplastics was more positive than that of conventional plastics. However, they had little experience in using bioplastics. Therefore, we investigated whether providing information would promote the intent to use bioplastics. As a result, information provision is likely to be effective in increasing the willingness to use bioplastics in addition to promoting positive perceptions. The participants indicated a significantly greater willingness to pay a higher price for single-use plastics (such as a 500 ml bottle of water), but not for durable plastics (such as a three-color ballpoint pen).

KEYWORDS

bioplastics, biodegradable plastics, knowledge, perceptions, bio-based plastics

Introduction

As the negative effects of plastics on the environment have become increasingly clear, bioplastics have attracted attention as a possible solution (Philp et al., 2013; Atiwesh et al., 2021) because they have the potential to become sustainable alternatives to conventional fossil-based plastics (Patel et al., 2018). Although there is no standardized definition of bioplastics to date (Filho et al., 2021), many studies use the term "bioplastics" when referring to bio-based, biodegradable materials (Jabeen et al., 2015). Bio-based plastics and biodegradable plastics are often confused with each other as eco-friendly plastics; however, they are not synonymous in terms of being eco-friendly (Rujnić-Sokele and Pilipović, 2017; Nandakumar et al., 2021). Bio-based plastics are wholly or partly derived from biomass, that is, material of biological origin excluding material embedded in geological formations and/or fossilized (Oever et al., 2017). In contrast, biodegradable plastics are made with polymers, which are amenable to natural processes of decay and able to decompose

accordingly (Razza and Innocenti, 2012). Specifically, bio-based plastics are classified on the basis of their raw material, while biodegradable plastics are classified according to their ability to degrade in the environment. Some bio-based plastics are biodegradable and some are not. Similarly, some biodegradable plastics are bio-based, while others are derived from conventional fossil-based sources. In this study, the term bioplastic is used as a generic term for bio-based plastics (i.e., wholly or partly derived from biomass) and biodegradable plastics (i.e., decompose in nature) based on the definition of the Japan Bioplastics Association (Japan Bioplastic Association, 2022).

The environmental impact also differs in relation to the types of plastics involved. It is generally assumed that the substitution of conventional fossil-based plastics with bio-based plastics leads to lower non-renewable energy use and greenhouse gas (GHG) emissions (Oever et al., 2017). However, some studies have indicated that excessive demand for biomass production leads to direct and indirect land use changes through the expansion of agricultural areas, which leads to increased GHG emissions (Piemonte and Gironi, 2010; Hottle et al., 2013; Mendes and Pedersen, 2021). Therefore, the assumption that there would be a reduced negative environmental impact when using bio-based plastics needs to be carefully assessed. Furthermore, it is often assumed that biodegradable plastics are effective in reducing environmental stress in the ocean and in coastal area pollution arising through plastic debris and microplastics as they are easily assimilated by microorganisms. However, the degradation process requires specific conditions and it does not always work as expected under natural conditions where many factors are uncontrollable (Nazareth et al., 2019). As such, bio-based plastics and biodegradable plastics need to be used in the right place at the right time, depending on the environmental considerations. Thus, with the variety of conditions that need to be considered in order to proceed with implementation, it would appear that bioplastics offer a potentially sustainable solution to mitigate the effects of plastic waste on the environment (Atiwesh et al., 2021).

The use of bioplastics is still limited, accounting for <1% of the plastic market in 2017 (European Bioplastics Market Data, 2017), but bioplastics have been predicted to have a 40% share by 2030 (Energy and Gold, 2016). To spread widely, a variety of issues need to be addressed, such as the development of industrial manufacturing and composting sites (Narancic and O'Connor, 2019), and a reduction in manufacturing costs. In addition to resolving supply and structural issues, there is a need to consider factors likely to drive the bioplastic market, such as increasing consumer awareness and the demand for sustainable products (Zhao et al., 2020).

However, the general population in many countries still seems unfamiliar with the bioplastic. One study reported that 57% of the German public had never even heard of bioplastics and that only ∼7% of them knew exactly what bioplastics were (Blesin et al., 2017). Similar levels of comprehension have been reported in Australia; Hoffman et al. (2019) surveyed 2,518 nationally representative Australians and reported that the Australian public's knowledge of bioplastics is low, but perception, particularly of biodegradable plastics, is positive. Klein et al. (2019) surveyed 1,673 nationally representative German and reported sociodemographic characteristics (i.e., gender, age, and education) have no significant influence on the attitude toward bioplastics, and indicated that it is necessary to improve knowledge concerning bioplastics including the understanding of the difference between bio-based and biodegradable plastics, that are often considered similar but with different properties, in order to expand the use of bioplastics.

It has been noted that providing information is effective in helping people choose sustainable products (Emberger-Klein and Menrad, 2018; Zhou et al., 2019). The need for information provision is also demonstrated in the field of bioplastics because consumers' perceptions have been found to be mixed: the term "bio" has been found to have both positive associations in terms of "naturalness" and in being "environmentally friendly," and negative associations in that it is linked to greater expense food shortages, deforestation, and inconvenience (Sijtsema et al., 2016; Blesin et al., 2017; Lynch et al., 2017). Lynch et al. (2017) indicated that citizens require reliable information on bioplastics to form their own opinion. In the case of Italian consumers, it has been found that providing relevant information increased the likelihood of choosing bioplastics as an alternative to single-use water bottles (Marchi et al., 2020).

Per capita disposal of single-use plastics is particularly high in Australia, the United States of America, South Korea, the United Kingdom, and Japan (Minderoo Foundation, 2021). In addition, Japan is the second-highest per capita disposal of plastic containers and packaging (UNEP, 2018). In Japan, all plastic waste is collected separately, with a recycling rate of 25% and a heat recovery rate of 57%. Yano et al. (2014) conducted life-cycle scenario analysis to evaluate the GHG reduction potential of the current recycling system for conventional fossil-based plastic products and of the processing system for converting fossil-based plastics to bio-based plastics since most bioplastics are bio-based plastics in Japan. An assessment of the GHG reduction potential showed that conversion to bio-based plastics could reduce GHG emissions by 14–20% over the entire lifecycle. In Japan, bio-based plastics (the predominant form i.e., over 90%) and biodegradable plastics are categorized as bioplastics, whereas globally, ∼45% of plastics are bio-based plastics and 55% are biodegradable. Although there is a growing interest in the issue of plastic waste in Japan, with 89% of respondents to a national survey saying they were concerned about plastic waste (Cabinet Office, 2021), the production of bioplastics remains very limited, amounting to ∼0.5% of total plastic product production (Ministry of Environment, 2020). As the Japanese government is aiming to increase the domestic

production of bioplastics from the current level of ∼0.07 to 2 million tons by 2030 (Ministry of Environment, 2021), understanding and acceptance on the part of consumers is important. Therefore, this study aimed to investigate the current state of knowledge and perception concerning bioplastics in Japan and the effectiveness of information provision in increasing the willingness to use bioplastics and promoting positive perceptions.

Materials and methods

Participants

A questionnaire was conducted involving Japanese citizens residing in Japan from November 24 to 25, 2021. Demographic questions to ascertain age and gender were used to ensure that the composition was similar to that of the Japanese population (Statistics Bureau of Japan, 2021) (Appendix 1 in Supplementary material 1), and we recruited 202 participants from a research company. Participants were asked to provide written informed consent for participation in the study after being informed about the purpose of the questionnaire. This study was conducted online, and prior to participating, all participants actively indicated their agreement to participate. The participants were rewarded for completing the questionnaire with a small shopping coupon.

Using *G**Power version 3.1.9.6 (Faul et al., 2007), we conducted a *post-hoc* power analysis assuming $d = 0.50$ (medium effect size), $\alpha = 0.05$, and $N = 202$. The calculated power of the test was 99, indicating that the sample size was sufficient.

Questionnaire survey

After demographic questions regarding age, gender and educational background, participants were asked about bioplastics (bio-based and biodegradable plastics) and conventional fossil-based plastics (as opposed to bioplastics). Then, information concerning bioplastics was provided. Third, the questions about bioplastics were asked again. All questions and response methods are presented in Appendix 2 in Supplementary material 2. Questionnaires were developed based on the study of Hoffman et al. (2019), where the participants responded using a five-point Likert scale. However, in this study, participants were requested to respond using a visual analog scale (VAS) ranging from 0 to 100, to gain a better sense and more granular view of their perceptions.

The questionnaire, information provision, and reevaluation were conducted separately for bio-based and biodegradable plastics. The survey included VAS, multiple-choice questions, and some open-ended questions.

Questions about bioplastics and conventional plastics

To determine the extent to which bioplastics are known in Japan, participants were asked about the subjective knowledge (i.e., the awareness of the term and thing), usage experience, and objective knowledge. Then, the perception of bioplastics, conventional fossil-based single-use and durable plastics to understand how bioplastics were comparatively evaluated. The questionnaire was developed with reference to the study by Hoffman et al. (2019).

Information provision about bioplastics

After the first round of questions, the participants were asked to read the following list concerning the expected benefits and precautions to be taken when using the respective plastics based on the description of the Japan Bioplastic Association (Japan Bioplastic Association, 2022):

Bio-based plastics

- Their raw materials contain a certain amount of renewable plant-derived resources.
- They are expected to have a positive effect on the prevention of global warming because plants absorb CO_2 through photosynthesis during their growth.
- They are also expected to save non-renewable resources.
- Some types are biodegradable and others are not. If a product is not biodegradable, it will remain in the environment without being broken down.

Biodegradable plastics

- They can be decomposed by microorganisms.
- They are expected to reduce plastic waste because they are broken down into water and CO_2.
- They are expected to have a positive effect on the recycling of waste because biodegradable plates and cups with leftover food can be composted.
- The speed of degradation depends on the types of plastic and the surrounding environment. Some decompose to one-fifth of their original weight within a year after being buried in the soil, while others do not decompose even after a year under the same conditions. Therefore, an understanding of appropriate disposal methods is required.

Reevaluation

The same questions were asked again regarding their perceptions and intention to use of bioplastics, with any changes recorded. In addition, after informing the participants that bioplastics tend to be more expensive than conventional plastics, we asked how much more the participants would be willing to pay for them compared to conventional plastics [i.e., in relation to a 500 ml bottle of water and a three-color ballpoint pen,

TABLE 1 Targeted questions regarding the knowledge of bioplastics.

	Yes	No	Do not know
All bio-based plastics are effective in reducing waste.	39.6%	**27.7%**	32.7%
All bio-based plastics have a positive effect on global warming.	**42.1%**	20.8%	37.1%
Some bio-based plastics are not biodegradable.	**41.6%**	9.4%	49.0%
All biodegradable plastics are effective in reducing waste.	**44.1%**	20.8%	35.1%
All biodegradable plastics have a positive effect on curbing global warming.	47.5%	**17.3%**	35.1%
Even biodegradable plastics have conditions for proper degradation.	**58.4%**	6.9%	34.7%

Note: Shaded and bold values are correct answer.

normally priced at 100 and 400 Japanese Yen (equivalent to 0.8 and 3.2 US dollar), respectively].

Results and discussion

Subjective and objective knowledge before providing information

At the start of the survey, the participants were asked about their subjective knowledge ("Do you know the term 'bioplastics'?" and "Are you familiar with bioplastics?"), and their experience with bioplastics.

Although 72.8% of the respondents knew of the term "bio-based plastics," only half of the respondents were familiar with bio-based plastics, and only 19.8% of them had actually used bio-based plastics. This finding indicated that there was a major difference between what people knew in terms of simple awareness of the "term" and what they knew in practice, and that they still had little experience in using bio-based plastics. A lack of objective knowledge about bio-based plastics was further revealed through more targeted questions (Table 1). In particular, more than 70% of the respondents were unsure or had incorrect perceptions about whether all bio-based plastics were effective in reducing waste. It was also revealed that only 40% of them knew of the positive effects of bio-based plastics as a measure against global warming and that some bio-based plastics were not biodegradable. Among those claiming to have knowledge, the responses showed only partial or incomplete knowledge. Furthermore, more than 30% of them chose the option "I do not know," probably due to the fact that there is not enough available information on the topic.

Although 51% of the respondents knew the term "biodegradable plastics," 40% of them actually knew what they were and 11% of them had actual experience of using biodegradable plastics, which were lower percentages than those found for bio-based plastics. Their objective knowledge was also checked with more targeted questions (Table 1). Regarding the disposal concern of biodegradable plastics (that not everything can be degraded), approximately 60% of the respondents understood that there were specific conditions required for degrading. In contrast, approximately half had an incorrect understanding of the effects of biodegradable plastics on global warming, indicating that, as with bio-based plastics, there was a discrepancy between subjective and objective knowledge, and that whatever objective knowledge they had was only partial. Furthermore, as was the case with bio-based plastics, more than 30% of the respondents chose the option "I do not know."

These findings were similar to those reported in other countries (Sijtsema et al., 2016; Hoffman et al., 2019), indicating that this level of knowledge is likely to be common worldwide.

Perceptions before providing information

Before being provided with relevant information, the participants were requested to rate bioplastics in terms of (i) bad/good, (ii) inconvenient/convenient, (iii) unnecessary/necessary, (iv) bad for the environment/good for the environment, and (v) non-hygienic/hygienic, by means of a VAS. For comparison, they were also asked to evaluate conventional fossil-based disposable and durable plastics (e.g., plastic bags and straws, and ballpoint pens and tableware, respectively) in the same way. The results showed that the participants significantly rated both bio-based and biodegradable plastics as relatively necessary, good for the environment, and hygienic compared to conventional plastics, while being perceived as inconvenient (Figure 1). Of the four types, conventional disposable plastics were rated relatively bad and unnecessary, and bad for the environment. In a previous study, biodegradable plastics were rated relatively good, good for the environment, and hygienic than conventional plastics (Hoffman et al., 2019). In particular, the fact that biodegradable plastics were rated good for the environment but inconvenient than conventional plastics, is consistent with the results of this study.

The willingness to use bioplastics was found to increase as more people rated them as good, convenient, necessary, good for the environment, and hygienic (Table 2). Therefore,

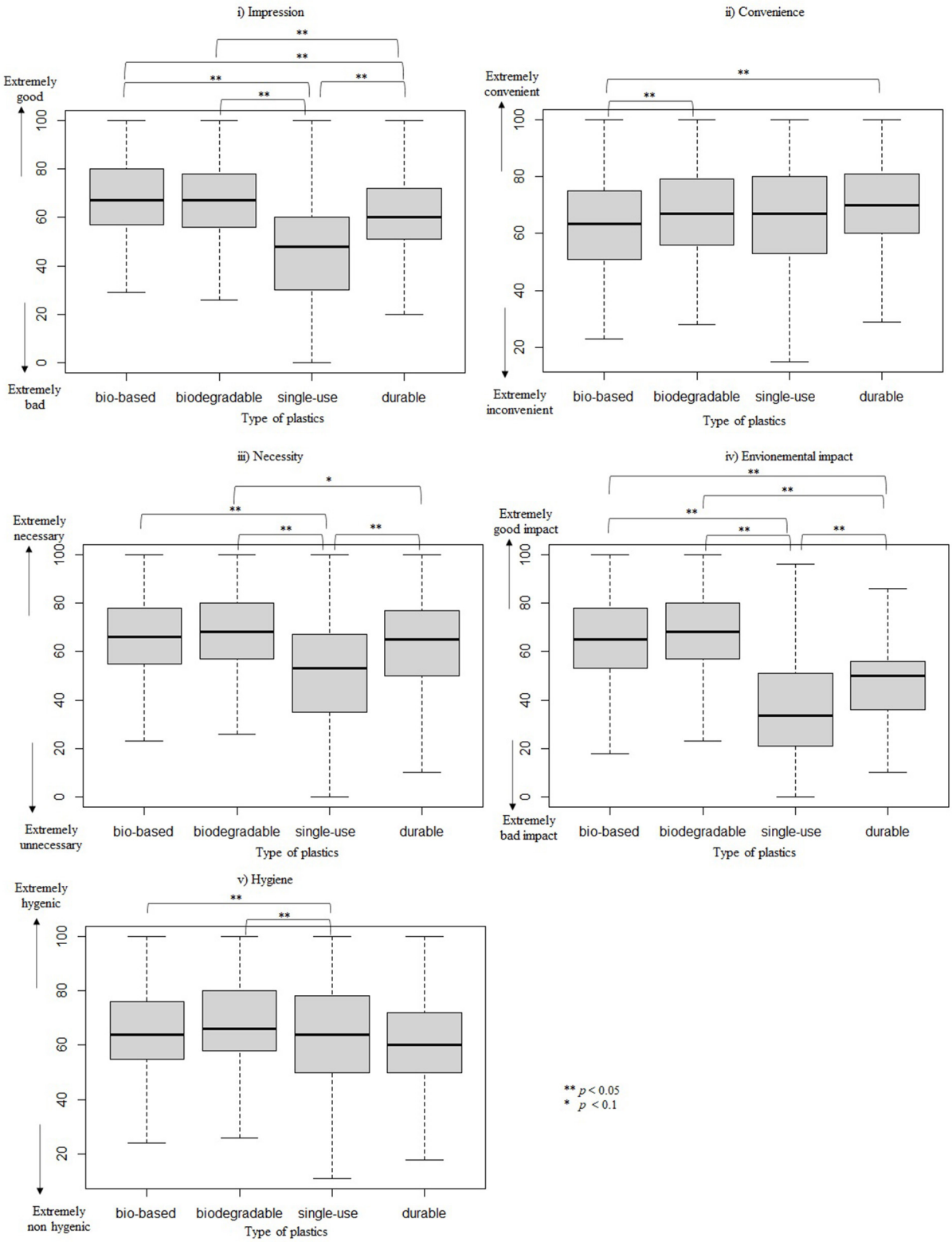

FIGURE 1
Perceptions of bioplastics and conventional plastics.

TABLE 2 Correlations between the willingness to use bioplastics and each evaluation axis.

	Bio-based plastics		Biodegradable plastics	
	r	*p*	*r*	*p*
(i) Bad/good	0.604	0.000	0.654	0.000
(ii) Inconvenient/convenient	0.530	0.000	0.624	0.000
(iii) Unnecessary/necessary	0.721	0.000	0.689	0.000
(iv) Good for environment/bad for environment	0.603	0.000	0.634	0.000
(v) Hygiene	0.474	0.000	0.545	0.000

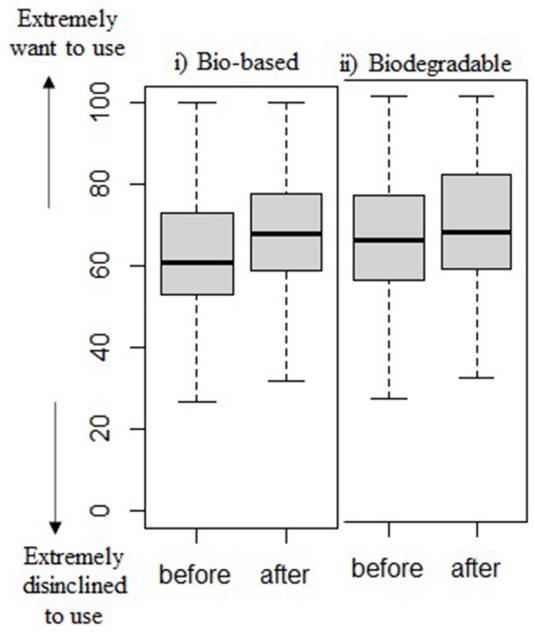

FIGURE 2
Willingness to use bioplastics before and after providing information.

improvements within these evaluation factors would likely have a positive effect on the use of bioplastics.

Effect of information provision

The provision of information significantly increased the willingness to use bio-based plastics ($W = 4{,}878$, $p = 0.000$) and biodegradable plastics ($W = 5{,}079$, $p = 0.001$) (Figure 2) with increased rating for (ii) convenient, (iii) necessary and (v) hygienic for bio-based plastics and (i) good, (ii) convenient, (iii) necessary and (v) hygienic for biodegradable plastics (Table 3). Bioplastics were rated significantly more necessary and hygienic than conventional plastics initially, but this increased further after information provision. The improvement in the perception that bio-based and biodegradable plastics are inconvenient can be considered encouraging in terms of the future adoption of the use of such plastics.

Regarding the willingness to pay for bioplastics, in the case of a 500 ml bottle of water at a current price of 100 Japanese yen, the participants indicated they were willing to pay a significantly higher price ($M = 126$ Japanese yen, t (201) $= 4.758$, $p = 0.000$) whereas, in the case of a three-color ballpoint pen at a current price of 400 Japanese yen, they indicated they would pay much the same price ($M = 396$ Japanese yen, t (201) $= -0.380$, $p = 0.705$). Thus, there seemed to be a willingness to replace disposable plastics with bioplastics but, there seemed to be less willingness for durable plastics. While previous research has indicated that a considerable percentage of respondents are "moderately" or "very" willing to pay extra in relation to bioplastics (Filho et al., 2021), it has been noted that bioplastics are an added value but not a deciding factor in purchases (Sijtsema et al., 2016). This study's findings suggest that Japanese consumers seemed to decide whether they ought to opt for bioplastics based on the nature of the plastic, i.e., whether it was disposable or durable. This result can be attributed to information provided concerning bioplastics. As Herrmann et al. (2020) suggested, consumers seem willing to pay for packaging that they perceive to be sustainable and are not willing to pay for packaging that they perceive to be non-sustainable or about which they are uncertain, and consumers are currently unsure what is the sustainable choice in relation to bioplastics. Hoffman et al. (2019) also suggested that there is no clear understanding among many consumers as to what the terms "bio-based" or "biodegradable" actually mean.

Conclusion

Excessive plastics production, use and disposal is an environmental problem that has attracted worldwide attention. For real-world application of bioplastics, there have been various scientific verifications and technical studies, and solutions in politics and business often focus on increasing consumers' environmental consciousness. However, consumers' perception of bioplastics is not limited to environmental consciousness and

TABLE 3 Difference in evaluation of bioplastics before and after information provision.

	Bio-based plastics		Biodegradable plastics	
	W	*p*	*W*	*p*
(i) Bad/good	8,459	0.751	4,730	0.000
(ii) Inconvenient/convenient	5,090	0.000	5,238	0.040
(iii) Unnecessary/necessary	5,560	0.015	5,189	0.033
(iv) Good for environment/bad for environment	7,216	0.398	6,538	0.446
(v) Hygiene	5,076	0.001	4,299	0.003

lack of knowledge is one of the reasons behind the adaption of positive initiatives by consumers (Rhein and Schmid, 2020). This study explored not only Japanese consumers' existing knowledge of bioplastics, but the effects of information provision. In particular, this study aimed to provide information on bio-based plastics and biodegradable plastics separately so that the right materials can be used in the right contexts for social implementation. The effectiveness of information provision has been indicated in many fields related to green consumption (Sexton and Sexton, 2014; Asensio and Delmas, 2015; Takahashi, 2021), and information provision of this study also improved the perception of bioplastics and willingness to use them. An Italian study found that information provision improved consumers' knowledge about plastics, but did not increase their willingness to pay for ecofriendly plastics (Marchi et al., 2020), whereas in this study willingness to pay for bioplastic alternative to single-use plastic was increased. It has been stressed that consumers are usually aware that they would pay a higher price for green products, and, therefore, their willingness to pay for such products must be supported by adequate information (Falcone and Imbert, 2018). It is possible that separate information provision for bio-based and biodegradable plastics resulted in willingness to pay more for green plastics in the case of single-use plastic due to better understanding of the properties of each and perceived effectiveness of the green options. However, further research is needed to reach a solid conclusion.

The study has several limitations. First, only a small number of people were surveyed. In order to examine the Japanese public's perception of bioplastics, the survey population was selected to match the characteristics of the general population, but more individuals need to be included in future studies to confirm this study's findings. Second, relevant information was provided through a short itemized list, but there are many ways to improve understanding and there is room for the further consideration of how information can be best provided. Third, while the participants were asked to evaluate their perceptions using five axes, namely: (i) bad/good, (ii) inconvenient/convenient, (iii) unnecessary/necessary, (iv) bad for environment/good for environment, and (v) non-hygienic/hygienic), future studies need to assess whether these axes are sufficient or whether further and better targeted approaches may be more appropriate. Fourth, it has been noted that the intention to use and purchase do not always lead to actual behavior. Actual behavior change needs to be studied in the future.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Hitotsubashi University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

YO: conceptualization, methodology, resources, validation, formal analysis, investigation, writing—original draft preparation, project administration, and funding acquisition. TK: conceptualization, methodology, data curation, formal analysis, and investigation. Both authors contributed to the article and approved the submitted version.

Conflict of interest

The 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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those

of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2022.927857/full#supplementary-material

References

Asensio, O., and Delmas, A. (2015). Nonprice incentives and energy conservation. *PNAS* 112, E510–E515. doi: 10.1073/pnas.1401880112

Atiwesh, G., Mikhael, A., Parrish, C. C., Banoub, J., and Le, T. T. (2021). Environmental impact of bioplastic use: a review. *Heliyon* 7, e07918. doi: 10.1016/j.heliyon.2021.e07918

Blesin, J. M., Jaspersen, M., and Möhring, W. (2017). Boosting plastics' image? Communicative challenges of innovative bioplastics. *J. Plast. Hist.* 3, 1–5.

Cabinet Office (2021). *Public Opinion Poll on Environmental Issues*. Available online at: https://survey.gov-online.go.jp/r01/r01-kankyou/2-1.html (accessed August 03, 2022).

Emberger-Klein, A., and Menrad, K. (2018). The effect of information provision on supermarket consumers' use of and preferences for carbon labels in Germany. *J. Clean. Prod.* 172, 253–263. doi: 10.1016/j.jclepro.2017.10.105

Energy and Gold (2016). *Global Bioplastics Market Predicted To Grow 350%*. Available online at: http://energyandgold.com/2016/03/10/an-enormous-investment-opportunity-in-a-rapidly-growing-space/ (accessed March 8, 2022).

European Bioplastics Market Data (2017). Available online at: https://docs.european-bioplastics.org/publications/market_data/2017/Report_Bioplastics_Market_Data_2017.pdf (accessed March 8, 2022).

Falcone, P. M., and Imbert, E. (2018). Social life cycle approach as a tool for promoting the market uptake of bio-based products from a consumer perspective. *Sustainability* 10, 1031. doi: 10.3390/su10041031

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Filho, W. L., Salvia, A. L., Bonoli, A., Saari, U. A., Voronova, V., Klõga, M., et al. (2021). An assessment of attitudes towards plastics and bioplastics in Europe. *Sci. Total Environ.* 755, 142732. doi: 10.1016/j.scitotenv.2020.142732

Herrmann, C., Rhein, S., and Strater, K. F. (2020). Consumers' sustainability-related perception of and willingness-to-pay for food packaging alternatives. *Resourc. Conserv. Recycl.* 181, 106219. doi: 10.1016/j.resconrec.2022.106219

Hoffman, L. K., Ashworth, P., Laycock, B., Pratt, S., and Lant, P. (2019). Public attitudes towards bioplastics—knowledge, perception and end-of-life management. *Resourc. Conserv. Recycl.* 151, 104479. doi: 10.1016/j.resconrec.2019.104479

Hottle, T. A., Bilec, M. M., and Landis, A. E. (2013). Sustainability assessments of bio-based polymers. *Polym. Degrad. Stabil.* 98, 1898–1907. doi: 10.1016/j.polymdegradstab.2013.06.016

Jabeen, N., Majid, I., and Nayik, G. A. (2015). Bioplastics and food packaging: A review. *Cogent Food Agric.* 1:1117749. doi: 10.1080/23311932.2015.1117749

Japan Bioplastic Association (2022). Available online at: http://www.jbpaweb.net/english/ (accessed July 20, 2022).

Klein, F., Klein, A. E., Menrad, K., Möhring, W., and Blesin, J. M. (2019). Influencing factors for the purchase intention of consumers choosing bioplastic products in Germany. *Sustain. Prod. Consum.* 19, 33–43. doi: 10.1016/j.spc.2019.01.004

Lynch, D. H. J., Klaassen, P., and Broerse, J. E. W. (2017). Unraveling Dutch citizens' perceptions on the bio-based economy: The case of bioplastics, bio-jetfuels and small-scale bio-refineries. *Ind. Crops Prod.* 106, 130–137. doi: 10.1016/j.indcrop.2016.10.035

Marchi, E. D., Pigliafreddo, S., Banterle, A., Parolini, M., and Cavaliere, A. (2020). Plastic packaging goes sustainable: an analysis of consumer preferences for plastic water bottles. *Environ. Sci. Policy* 114, 305–311. doi: 10.1016/j.envsci.2020.08.014

Mendes, A. C., and Pedersen, G. A. (2021). Perspectives on sustainable food packaging:– is bio-based plastics a solution? *Trends Food Sci. Technol.* 112, 839–846. doi: 10.1016/j.tifs.2021.03.049

Minderoo Foundation (2021). *Plastic Waster Makers Index: Revealing the Source of the Single-Use Plastics Crisis*. Available online at: https://cdn.minderoo.org/content/uploads/2021/05/27094234/20211105-Plastic-Waste-Makers-Index.pdf (accessed March 8, 2022).

Ministry of Environment (2020). *The Domestic and International Situation of Plastics*. Available online at: https://www.env.go.jp/council/03recycle/20201120t2.pdf (accessed March 8, 2022).

Ministry of Environment (2021). *Roadmap for the Introduction of Bioplastics*. Available online at: http://www.env.go.jp/recycle/plastic/bio/pdf/bioplasticRoadmap_210329.pdf (accessed March 8, 2022).

Nandakumar, A., Chuah, J., and Sudesh, K. (2021). Bioplastics: a boon or bane? *Renew. Sustain. Energy Rev.* 147, 111237. doi: 10.1016/j.rser.2021.111237

Narancic, T., and O'Connor, K. E. (2019). Plastic waste as a global challenge: are biodegradable plastics the answer to the plastic waste problem? *Microbiology* 165, 129–137. doi: 10.1099/mic.0.000749

Nazareth, M., Marques, M. R. C., Leite, M. C. A., and Castro, I. B. (2019). Commercial plastics claiming biodegradable status: Is this also accurate for marine environments? *J. Hazard. Mater.* 366, 714–722. doi: 10.1016/j.jhazmat.2018.12.052

Oever, V. M., Molenveld, K., Zee, M., and Bos, H. (2017). *Bio-Based and Biodegradable Plastics-Facts and Figures. Focus on food packaging in the Netherlands*. Wageningen: Wageningen Food and Biobased Research.

Patel, M. K., Bechu, A., Villegas, J. D., Bergez-Lacoste, M., Yeung, K., Murphy, R., et al. (2018). Second-generation bio-based plastics are becoming a reality—non-renewable energy and greenhouse gas (GHG) balance of succinic acid-based plastic end products made from lignocellulosic biomass. *Biofuels Bioprod. Biorefin.* 12, 426–441. doi: 10.1002/bbb.1849

Philp, J. C., Bartsev, A., Ritchie, R. J., Baucher, M. A., and Guy, K. (2013). Bioplastics science from a policy vantage point. *New Biotechnol.* 30, 635–646. doi: 10.1016/j.nbt.2012.11.021

Piemonte, V., and Gironi, F. (2010). Land-use change emissions: How green are the bioplastics? *Environ. Progress Sustain. Energy* 30, 685–691. doi: 10.1002/ep.10518

Razza, F., and Innocenti, F. D. (2012). Bioplastics from renewable resources: the benefits of biodegradability. *Asia-Pac. J. Chem. Eng.* 7, S301–S309. doi: 10.1002/apj.1648

Rhein, S., and Schmid, M. (2020). Consumers' awareness of plastic packaging: more than just environmental concerns. *Resourc. Conserv. Recycl.* 162, 105063. doi: 10.1016/j.resconrec.2020.105063

Rujnić-Sokele, M., and Pilipović, A. (2017). Challenges and opportunities of biodegradable plastics: a mini review. *Waste Manag. Res.* 35, 132–140. doi: 10.1177/0734242X16683272

Sexton, S., and Sexton, A. (2014). Conspicuous conservation: the Prius halo and willingness to pay for environmental bona fides. *J. Environ. Econ. Manag.* 37, 303–317. doi: 10.1016/j.jeem.2013.11.004

Sijtsema, S. J., Onwezen, M. C., Reinders, M. J., Dagevos, H., Partanen, A., and Meeusen, M. (2016). Consumer perception of bio-based products—an exploratory study in 5 European countries. *NJAS Wageningen J. Life Sci.* 77, 61–69. doi: 10.1016/j.njas.2016.03.007

Statistics Bureau of Japan (2021). *Population Estimate* (in Japanese). Available online at: https://www.stat.go.jp/data/jinsui/pdf/202110.pdf (accessed March 8, 2022).

Takahashi, R. (2021). How to stimulate environmentally friendly consumption: evidence from a nationwide social experiment in Japan to promote eco-friendly coffee. *Ecol. Econ.* 186, 107082. doi: 10.1016/j.ecolecon.2021.107082

UNEP (2018). *Single-Use Plastics: A Roadmap for Sustainability*. Available online at: https://www.unep.org/ietc/ja/node/53?%2Fresources%2Fpublication%2Fsingle-use-plastics-roadmap-sustainability= (accessed March 8, 2022).

Yano, J., Hirai, Y., Sakai, S., and Tsubota, J. (2014). Greenhouse gas emissions from the treatment of household plastic containers and packaging: replacement with biomass-based materials. *Waste Manag. Res.* 32, 304–316. doi: 10.1177/0734242X14525820

Zhao, X., Cornish, K., and Vodovoz, Y. (2020). Narrowing the gap for bioplastic use in food packaging: An update. *Environ. Sci. Technol.* 54, 4712–4732. doi: 10.1021/acs.est.9b03755

Zhou, S., Wang, H., Li, S., Chen, Y., and Wu, J. (2019). Carbon labels and "horizontal location effect": Can carbon labels increase the choice of green product? *Glob. Ecol. Conserv.* 18, e00609. doi: 10.1016/j.gecco.2019.e00609