Current Research in Environmental Sustainability 7 (2024) 100246

Contents lists available at ScienceDirect

Current Research in Environmental Sustainability

journal homepage: www.sciencedirect.com/journal/current-research-in-environmental-sustainability

Implications of consumer orientation towards environmental sustainability on the uptake of bio-based and biodegradable plastics

Carly A. Fletcher [a], Selena Aureli [b,*], Eleonora Foschi [b], Walter Leal Filho [c], Jelena Barbir [c], Freddys R. Beltrán [d], Liisa Lehtinen [e], Craig E. Banks [a]

[a] *Department of Natural Sciences, Manchester Metropolitan University, UK*
[b] *Department of Management, University of Bologna, Italy*
[c] *Faculty of Life Sciences, Hamburg University of Applied Sciences, Germany*
[d] *Dpartment of Ingeniería Química Industrial y Medio Ambiente, Universidad Politécnica de Madrid, Spain*
[e] *Faculty of Engineering and Business, Turku University of Applied Sciences, Finland*

ARTICLE INFO

Keywords:
Bio-based
Biodegradable
Plastics
Market uptake
Consumer behavior
End-of-life management
Circular economy
Consumer attitude

ABSTRACT

The overconsumption of conventional plastics has led to several environmental and social-economic issues related to plastic pollution, carbon emissions and resource depletion. Acknowledging these issues, the introduction of alternatives such as bioplastics has been promoted by national, supranational, and international organizations. However, the market for such materials is still niche, where businesses are uncertain about the benefits and costs associated with the use of these innovative materials. Successful (and sustainable) uptake of such alternatives will depend on public acceptance and changes in consumer behavior. Therefore, this study aims to explore how consumers' orientation towards environmental sustainability is related to consumer utilization of alternatives such as bio-based and biodegradable plastics. Consumer knowledge and performance expectations of these materials are also analyzed. This study employed a predominately quantitative research approach, where a self-administered online survey was used to collect the opinions of consumers across society using a snowball sampling technique. Results show continued consumer confusion, unrealistic expectations, and a value-action gap. These elements may have consequences for market uptake and broader implications across the value chain. A key implication is that both policy makers and businesses should address these barriers through enhanced communication of relevant information alongside improved consumer awareness and education.

1. Introduction

Plastics are a successful story, due to their versatility and advantageous characteristics (e.g., durability, flexibility, and light weightiness), contributing to economic development and environmental efficiency (e.g., prolonging the lifespan of food) (Bishop et al., 2020). However, society's continued reliance on conventional plastics has caused substantial environmental challenges (Prata et al., 2021). As a consequence of being largely petroleum-based, considerable energy requirements and carbon emissions are characteristic of their production, transportation, and refinement (Stasiškienė et al., 2022). Furthermore, while durability is beneficial for some applications, this attribute becomes detrimental in single-use products, especially when unintentionally discharged into the environment. Both macroplastics and microplastics (fragments <5 mm) have direct and indirect ramifications for ecosystem and human health, as well as socioeconomic impacts (Prata et al., 2021; Vethaak and Legler, 2021; Kaufman et al., 2021).

Issues associated with plastics have been acknowledged at national, supranational, and international levels (Stasiškienė et al., 2022). Indeed, over several decades the European Union has introduced a range of policy measures, evolving from waste valorization to waste prevention (European Commission [EC], 2020b). Most recently, their Plastics Strategy European Commission [EC], 2018), Green Deal (European Commission [EC], 2020c) and Bioeconomy Strategy (European Commission [EC], 2020), all seek to address the problems associated with plastics mismanagement by supporting the introduction of alternatives,

* Corresponding author.
E-mail addresses: carlyfletcher1@gmail.com (C.A. Fletcher), selena.aureli@unibo.it (S. Aureli), eleonora.foschi3@unibo.it (E. Foschi), walter.leal2@haw-hamburg.de (W.L. Filho), Jelena.Barbir@haw-hamburg.de (J. Barbir), f.beltran@upm.es (F.R. Beltrán), Liisa.Lehtinen@turkuamk.fi (L. Lehtinen), c.banks@mmu.ac.uk (C.E. Banks).

https://doi.org/10.1016/j.crsust.2024.100246
Received 22 July 2023; Received in revised form 24 February 2024; Accepted 26 February 2024
Available online 8 March 2024

restricting single-use products and promoting circular economy practices (European Union [EU], 2019).

Bio-based and biodegradable plastics are possible progressive substitutes of conventional plastics. According to both academia and industry (Nanda et al., 2022), this solution seems promising since it is sourced from biological feedstock and based on biodegradable and often compostable properties. Being sourced from renewable resources and produced in biorefineries, bio-based plastics record lower greenhouse gas (GHG) emissions compared with oil refinement processes (Harding et al., 2007; Chen et al., 2016; Bishop et al., 2021). Biodegradability reduces (to some extent) negative impacts on natural and human ecosystems, especially when these materials are mismanaged at the end of their life. In certain circumstances, i.e., when compostable, correctly collected and treated under controlled industrial conditions, biodegradable plastics can be returned to the natural environment in the forms of CO_2 and H_2O and biomass, thus potentially becoming a farming resource and preserving value as circular economy principles command (Kang et al., 2022; Cristóbal et al., 2023).

Adopting such innovative materials requires investments, but businesses are uncertain because they perceive several challenges and threats (Foschi et al., 2023) from the scarce availability of feedstocks to the difficulties in assessing socio-economic impacts, and the uncertainty on consumer acceptance and demand (Falcone and Imbert, 2018; Ali et al., 2023). The latter aspect may have a strong impact on bioeconomy uptake, which is also related to consumer interests and awareness (D'Adamo et al., 2020). In general, the role of consumers in fostering sustainability is described in the literature, where it has been acknowledged that if consumer behavior does not change, environmentally sound products and services will not flourish (Kostadinova, 2016; White et al., 2019; Hosta and Zabkar, 2021). Although scholars used to evidence the resistance of consumers to change purchase routines (Schneider and Hall, 2011), today consumers seem to be more attentive to the environmental implications of their decisions (Hares et al., 2010; Camilleri et al., 2019). Research has recently investigated drivers and motivations for consumers' 'green' purchasing choices under different lenses (Newton et al., 2015; Trivedi et al., 2018; Testa et al., 2020). The biggest debate has focused on consumers' willingness to pay a premium price for sustainable goods (Morone et al., 2021) and therefore, around business and financial impacts of consumers' behavior (Zwicker et al., 2021). Less attention has been devoted to the effects of consumers' decisions along the entire value chain (Claudy and Peterson, 2022; Vidal-Ayuso et al., 2023). Considering consumers at the "*center of the value chain*" (Maitre-Ekern and Dalhammar, 2019) is pivotal to the circular economy paradigm that aims to transform current production and consumption patterns towards more reliable models. In this regard, Shevchenko et al. (2023) stressed the importance of addressing this gap and better analyzing the role of consumers in multiple life cycle stages, including purchasing, usage and End-of-Life (EoL).

Very recent studies (Leal Filho et al., 2022; Fletcher et al., 2021; Barbir et al., 2021; Findrik and Meixner, 2023; Van Tonder et al., 2023) have identified a clear link between consumer psychological traits and personal values, their attitudes to the preservation of the environment and purchasing behavior. Nevertheless, research acknowledge the need for more studies since 'green consumption behavior' is undeniably complex (Uehara et al., 2023; Herrmann et al., 2022). Several factors may affect consumer behavior with lack of knowledge on product features and confusion on disposal patterns being strongly associated to scarce consumers' willingness to pay for such products (Ansink et al., 2022; Foschi et al., 2023). Consumer acceptance can be enhanced by providing more information on product performance (Martin et al., 2018) and by means of reliable certifications, standards and labels (Morone et al., 2021) that can help consumers and businesses navigate the complex landscape of bio-based materials and at the same time give security to investors (Purkus et al., 2018; Falcone and Imbert, 2019). Lastly, consumers may have unrealistic expectations that can hinder consumers purchase (Falcone and Imbert, 2018), while realistic ones facilitate the purchase decisions.

Thus, building upon previous literature, the objective of this study is to explore the implications of consumer orientation towards environmental sustainability on the uptake of bio-based and biodegradable plastics. Based on a conceptual framework, this study uses consumers' environmental self-identity and life-style actions to build profiles of customers that have different orientations towards environmental sustainability, which is assumed to impact consumer's purchase behavior of bio-based and biodegradable products. In addition and differently from previous studies, we include consumers' knowledge and expectations in the mixing pot of factors that may affect purchase, use and disposal behaviors. Finally, this study is based on a multi-country analysis, providing interesting context-dependent findings, which could be further explored in light of national regulation and culture (Chwialkowska et al., 2020).

2. Theoretical background and hypothesis development

To provide context, and to help aid hypothesis development, this section first introduces alternative plastics and then focuses on how confusion on terminology and waste disposal patterns characterize the uptake of materials. Finally, it presents the antecedents or factors that affect consumer purchase behavior.

2.1. Introduction to alternative plastics

As potential substitutes for conventional plastics, alternative plastics aim to lower environmental impacts by reducing waste accumulation and optimizing renewable resource use. When biodegradable, these materials also try to address the negative impacts of conventional plastics in ecosystems and their subsequent accumulation. However, not all biodegradable plastics can be composted in the same way, with some requiring specific industrial conditions (Stasiškienė et al., 2022) and not all biodegradable plastics are obtained from renewable resources. That being said, for the remainder of this paper the term "bioplastic" may be used to refer to the group of plastics that are bio-based and/or biodegradable.

Research indicates that the growing demand for alternative materials has led to the development of a wide array of materials (from PBAT, PLA, PHA to bio-PET and bio-PE). The uptake of such materials is driven by three key aspects: market demand, strategic differentiation decisions, and companies' efforts to embed sustainability as a core value (Döhler et al., 2022). Both market and legislative pressure for climate adaptation plans are making bioplastics attractive, but they still remain a niche market.

2.2. Confusion around complex and fragmented terminologies

The complexity created by the use of different terms can lead to confusion and misinterpretation for both consumers and technologists. For instance, both Klein et al. (2019) and Scarpi et al. (2021) argue that the term "bioplastic" is not easy for consumers to understand. The term "bioplastic" is commonly used to describe materials that are bio-based and/or biodegradable (European Bioplastics [EUBP], 2018), as such it is often the case that users believe these terms to be interchangeable (García-Depraect et al., 2021), where it is thought that bio-based plastics are, by extension, biodegradable. In reality, there are non-biodegradable bio-based plastics (i.e., bio-PE, bio-PET), as well as fossil-based biodegradable plastics (i.e., PCL, PBAT) (European Bioplastics [EUBP], 2018). Another common misinterpretation comes from the terms biodegradable and compostable. The former does not include any time scale nowadays, while the latter presents strict requirements regarding degradation and decomposition, as well as the quality of the resultant compost (Stasiškienė et al., 2022). As recently recommended by the EU Commission in a strategic policy document (2022), the incorrect use of seemingly interchangeable terms to describe materials should be avoided, i.e., whilst all products that are compostable are also biodegradable, the reverse is not valid, as not all biodegradable materials will degrade under composting conditions (Philp et al., 2013).

Across multiple grey-literature sources, the usage of different terminologies and labels to market alternative plastics (e.g., bio-based, bioplastics, (bio)degradable, compostable, recyclable, recycled content, bio-derived, etc.) has been highlighted as a potential source of consumer confusion (Fletcher et al., 2021). Such consumer confusion is highly debated in the literature. For example, Uehara et al. (2023) reveal that more than half of their Japanese respondents were unaware of the distinctions between bio-based and biodegradable. Similarly, surveys conducted in Ireland and Germany report poor knowledge of bioplastics (Neves et al., 2020; Blesin et al., 2017). Such confusion is also caused by missing or fragmented labelling schemes (Findrik and Meixner, 2023).

2.3. Confusion on waste management paths

Another key aspect that may hinder consumers from taking informed decisions is the confusion surrounding waste collection and recycling routes associated to alternative plastics. This confusion may increase uncertainty with regard to environmental benefits and also have practical implications on the circularity of these materials when reaching their EoL.

It is well known that conventional plastic waste has been largely managed through mechanical recycling, incineration, or landfill (Zhao et al., 2018; Paletta et al., 2019). In light of evolving EU policies, routes that maximize reuse and recycling such as Deposit Return Schemes (DRS) and dedicated collection systems have become more favorable (European Commission [EC], 2018) but when alternative plastics are considered, other strategies become available. Most anticipated is material recovery through organic recycling, provided that the material is suitable. Compostable plastics certified by the European standard EN 13432 can be disposed of alongside organic biowaste, where they are converted to biomass in industrial composting facilities (via aerobic degradation). Alternatively, treatment via anaerobic digestion produces biofuels as a useful end-product (Stasiškienė et al., 2022).

Non-biodegradable bio-based plastics, such as those known as “drop in plastics”, should not require any further consideration than that given to their conventional counterparts, since they can be collected and managed via established recycling routes (Niaounakis, 2019; Spierling et al., 2018). While various studies indicate that mechanical recycling may be suitable for other (non- “drop in”) bio-based plastics such as PLA, some biodegradable plastics have been shown to be susceptible to degradation during reprocessing (Badia and Ribes-Greus, 2016). Finally, biodegradable plastics which are not compostable do not provide extra value in the collection process, as they cannot be properly valorized via organic recycling. In this case, the only plausible route (also determined by relatively small volumes) remains incineration nowadays (Stasiškienė et al., 2022). In relation to the revised EU ETS, the presence of bio-based plastics within the waste stream may counteract the financial disincentive for incineration. Indeed, if bio-based plastics are treated similarly to bioliquids, adherence to a sustainability criterion would allow an emission factor of zero to be applied to the biomass fraction (Department for Business, Energy and Industrial Strategy [BEIS], 2021).

Given the different possible waste management paths for bioplastics, it seems necessary for consumers to be guided in proper waste disposal through the use of labels, e.g., the Seedling-label (European Bioplastics [EUBP], 2017). However, despite strong market signals and normative pressures, converters and users (and ultimately consumers) are often challenged by the multitude of labelling systems used across Europe, USA, and Asia (Filiciotto and Rothenberg, 2021; Rosenboom et al., 2022). Unaware of the nuances discussed above and relying on information (via labelling) that may not give localized detail, consumers may select an incorrect disposal route, including littering in open environments (Stasiškienė et al., 2022; Neves et al., 2020).

2.4. Consumer expectations

Consumer expectations refer to the capability of a product or service to achieve a certain level of performance or goals. Expectations do not emerge in a vacuum: they are linked and usually informed by consumers' knowledge and past experiences towards the issues at stake. Expectations are critical because they can affect purchase decisions and may have a significant impact on market trends. When referring to bio-based and biodegradable plastics, it has been suggested that consumers have developed both environmental and technical expectations.

With respect to technical performance, Falcone and Imbert (2018) suggest that alternative plastics must face many challenges, which consumer expectations can further exacerbate. It is argued that consumers expect alternative plastic products to perform to, not only an equal, but to a higher standard of technical performance when compared with conventional plastics. However, consumers' perceptions about the low durability of these materials negatively affect purchasing decisions. Even so, consumers' expectations might not be grounded on exact knowledge of actual technical performance of these materials.

Moreover, environmental performance is given a higher level of importance compared to the technical aspects (Notaro et al., 2022). Ahmed et al. (2018) noted that biodegradable plastics seem to be held to a higher standard for environmental performance compared to fossil plastics. This positive trend aligns with consumer expectations that bio-based and biodegradable plastics are connected to positive environmental outcomes. In addition, eco-conscious consumers have positively reflected on the anticipated “eco-credentials” of biodegradable plastics, whereby they are reputed to address the microplastics problem (Edo et al., 2022) and/or are able to return resources to the biosphere i.e., via composting (Testa et al., 2021). Such consumer expectations have been shown to have implications on subsequent behavior.

Nevertheless, consumers' expectations on environmental impacts of these materials can be challenged by uncertainty (Findrik and Meixner, 2023). For example, there is a knowledge gap about the effect of different environments on the biodegradation process of biodegradable plastics (Uehara et al., 2023). Gutierrez Tano et al. (2022) evidence that comparative Life Cycle Assessment (LCA) studies have shown different impacts. Results are also affected by the type of feedstock, additives, production processes, and disposal patterns (Amasawa et al., 2021; Bishop et al., 2021; Findrik and Meixner, 2023). On one hand, research indicates that bio-based plastics can reduce emissions by 25%, even when sourced from virgin (albeit renewable) resources (Rosenboom et al., 2022). On the other hand, the feedstock used to produce these materials is often under scrutiny, particularly concerning land use and food security (Zheng and Suh, 2019). When there is a low capability to appreciate how alternatives compare with conventional plastics (Leal Filho et al., 2022), stakeholder skepticism may emerge, as well as negative expectations that, in turn, generate reluctance to buy alternative plastics (Klein et al., 2019).

2.5. Antecedents of green purchasing behavior

Environmental-friendly or green purchasing behavior is largely investigated by consumer research. According to Scarpi et al. (2021), this stream of research can be used to understand antecedents for consumer's purchase of bio-based and biodegradable products.

Green purchasing is usually analyzed in light of the Theory of Planned Behavior (TPB) or the Theory of Self-Identity (TSI). The first focuses on values, attitudes and intentions that affect the consumer's decision process and consequently actual purchases (Mehta and Chahal, 2021). Attitude is usually operationalized as beliefs and feelings related to a product or service. With reference to the case of bio-based products, both Notaro et al. (2022) and Gutiérrez Taño et al. (2021) report that strong positive attitudes towards bioplastics drive purchasing behaviors. TSI instead posits that an individual's overall self-perception – based on values, beliefs, goals and habits - may strongly affect intentions and purchase behavior (Gao et al., 2009). Green self-identity means that a person identifies with the typical green consumer (Sparks and Shepherd, 1992) and this identity strongly affects eco-friendly behaviors (Barbarossa et al., 2017). According to recent studies, the self-identity concept plays a significant role in predicting intentions, over and above attitudes, and impacting independently (Dean et al., 2012). This green self-identify has been also labelled as eco-consciousnesses.

Based on the literature review, the different elements that may affect consumer behavior have been summarized in the conceptual framework of Fig. 1, which focuses on three key elements: i) consumers' orientation towards environmental sustainability, ii) consumers' knowledge about alternative plastics, and iii) consumers' expectations. Orientation towards environmental sustainability has been conceptualized in terms of a respondent's environmental self-identity (what they think) and his/her actions (what they do). We opted to build on this approach by echoing Sparks and Shepherd (1992) green self-identity and also including actions, because, as highlighted by Carrington et al. (2010), focusing solely on beliefs or intentions does not allow for understanding nor prediction of behaviors. An approach also employed by (Gilg et al., 2005). Consumer behavior (utilization) has been operationalized as (1) having the imperative to search for alternative plastics, (2) purchasing bio-based and/or biodegradable plastic products and (3) being pleased with routinely replacement of conventional plastic products.

This framework also suggests that orientation towards environmental sustainability and utilization behavior can be shaped by how much knowledge a consumer has about product properties. Confusion (due to poor knowledge) around the complex and fragmented terminology used has been widely reported (Klein et al., 2019; Scarpi et al., 2021). Also consumer expectations regarding performance can influence purchasing behaviors and can be linked to past experience and current level of knowledge (Falcone and Imbert, 2018; Findrik and Meixner, 2023; Uehara et al., 2023).

To interrogate this conceptual framework, this study tested the following H statements;

[H1] Consumers with stronger orientation towards environmental sustainability are more likely to utilize alternative plastics.

[H2] Consumers with stronger orientation towards environmental sustainability have a greater level of knowledge on both the terminology used to describe alternative plastics commercially and their correct waste disposal routes.

[H3] Consumers with stronger orientation towards environmental sustainability have a greater level of expectation regarding the technical and environmental performance of alternative plastics.

3. Materials and methods

To test our hypothesis, this study implemented an online survey. The data collection method was developed to be primarily quantitative, but scope was provided for respondents to also provide qualitative inputs (e.g., to explain the reasoning behind a response or to elaborate on certain points). Development of the survey questions was informed by the literature and is a result of the interactions among the authors.

First, questions were formulated to understand environmental self-identity and life-style actions which combine to build consumers' orientation towards environmental sustainability. Replicating and adapting the two item scales used by Sparks and Shepherd (1992), two questions from the survey were used as a proxy for green self-identity, where they were asked (1) How environmentally conscious do you think you are? and (2) When purchasing everyday products, how important is environmental sustainability in the decision-making process? To understand actual lifestyle choices, respondents were asked how often they completed ten actions related to environmental sustainability (e.g., buy unpackaged products, buy local, reuse containers, waste recycling, separate organic waste, etc.).

Scrutinizing participants green self-identity and self-reported actions allowed for the identification of four different categories (see Table 1) to describe a consumer's orientation towards environmental sustainability. Categorization was instrumental to check for H1. Self-reported actions were included because we deemed that solely focusing on perceptions might not fully uncover consumers' views. This procedure had the merit to highlight the existence of a 'value-action gap' among several consumers (difference between reported environmental self-identity and lifestyle actions) (Flynn et al., 2009).

Another block of questions was formulated to understand current factors highlighted in the literature that can act as barriers to the uptake of alternative solutions. In line with H2, questions were designed to evaluate: i) knowledge (/confusion) on terminology and ii) knowledge (/confusion) on disposal. Accordingly, questions were designed to assess the level at which the respondents recognize and understand the different terms and labels used to market alternative plastics. Then, questions were developed to understand and evaluate the respondents' level of confidence and knowledge regarding the correct waste disposal

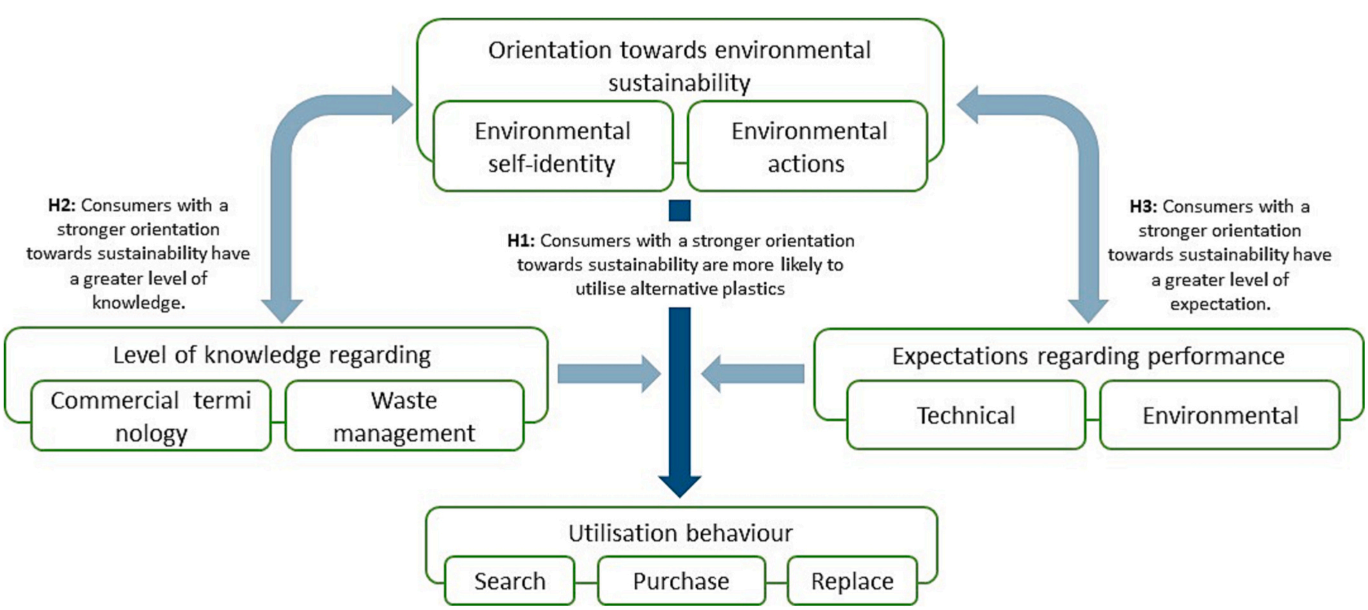

Fig. 1. Graphical illustration of conceptual framework.

Table 1
Categories of respondents grouped by cluster analysis. Includes number (n) of respondents per group and characterization of groups based on average frequency of environmental actions and self-reported environmental self-identity.

No	Term	n	Actions	Self-identity	Characterization
1	Environmentally Indifferent (EI)	20	1.83	1.70	These respondents do not consider themselves to be that sustainable, reporting low scores for environmental self-identity. Their actions reflect this self-identity, undertaking sustainability actions on a yearly-seasonal basis.
2	Environmentally Aware (EA)	33	2.69	3.21	These respondents consider themselves to be the most sustainable of all the groups, reporting high scores for environmental self-identity. However, their actions do not reflect their beliefs, where sustainability actions are undertaken on a seasonal-monthly basis. This group has the highest value-action gap.
3	Environmentally Galvanized (EG)	40	2.89	1.98	These respondents do not consider themselves to be green consumers, reporting an average score for environmental self-identity. However, their sustainability actions are undertaken on a seasonal-monthly basis, denoting a strong actual commitment.
4	Environmentally Conscientious (EC)	27	3.74	3.15	These respondents consider themselves to be environmentally friendly and their actions reflect these beliefs, undertaking sustainability actions on a monthly-weekly basis.

route for different alternative plastics.

Finally, to investigate H3, questions were developed to ascertain the levels of expectation respondents had for alternative plastic products in terms of technical and environmental performance when compared with traditional plastics (greater level of expectation, same level of expectation, or lower level of expectation).

Closed questions were employed to measure opinions using Likert-type rating scales and/or multiple choice based on a range of statements, with optional open comment boxes for elaboration. To reduce response bias, the closed questions included 'don't know' and 'not applicable' options so that respondents were not forced to specify an opinion (Friedman and Amoo, 1999). The questionnaire was first reviewed for improvements by circular economy, sustainability, waste management, and plastics research experts Then, a pilot study was also conducted to ensure clarity and comprehensiveness. Some revisions were made to address minor issues.

The survey instrument was hosted online, delivered via MS Forms (Microsoft Office) and targeted consumers over 18 years old who used plastic products day-to-day. The questionnaire was written in English but solicited opinions internationally in order to collect cross-country opinions as suggested by Herbes et al. (2018). The survey link was shared via social media and through professional networks, such as LinkedIn. This survey relied on the snowball sampling technique (which continues on the basis of referrals across networks, as adopted by Notaro et al., 2022) to collect a relevant sample size.

Quantitative data from closed questions were analyzed using Microsoft Excel (365) and SPSS (v.27). Cluster (k-mean) analysis based on green self-identity and environmental actions was used to categorize the respondents in different groups to reflect their orientation towards environmental sustainability. This approach was based on that employed by Gilg et al. (2005). Survey questions can be found in the Appendix. Respondents were first ranked by their green self-identity (Ranked 0 to 4) and how often they undertook sustainable actions (average score), reported as Rank #1 = 0.91 to Rank #120 = 4.55. Initial cluster points were set according to the minimum (Rank #1), maximum (Rank #120) and both interquartile range outliers (Ranks #40 and #80). Each data point was then compared against the four initial cluster points as sum of squared difference (using "=SUMXMY2" function in excel), with the lowest result indicating which group the data point belonged to. This was re-run multiple times (each time the initial cluster points were changed to reflect the average of that group from the previous round of clustering) until the groups remained static.

The cluster (k-mean) analysis organized the respondents into four groups to reflect their orientation towards sustainability (environmentally conscientious = EC; environmentally galvanized = EG; environmentally aware = EA; and environmentally indifferent = EI). Each group is characterized by a certain level of environmental self-identity and differing levels of action having environmental impacts (as described in Table 1).

This study was indicative in nature and analysis was carried out at the level of individual questions, where description statistics (frequency and % of responses) were used to assess responses and the Kruskal-Wallis H test was used to test for differences between the four groups. Unless otherwise stated, differences between groups were insignificant and did not achieve a significance level of 90% or more ($p \leq 0.1$). Qualitative data (from open comment boxes) was analyzed through thematic analysis to identify areas of agreement and conflict. Here, any areas of note, or any particularly pertinent quotations, have been highlighted to elaborate on the quantitative results.

4. Results

In total, 120 responses were collected; a breakdown of the respondent profile is presented in Table 2. Overall, the profile highlights input from across society, where respondents were predominantly from Europe (e.g., UK, Italy, Germany), and Malaysia. With respect to

Table 2
Breakdown of respondent profile, including age, occupation, gender, highest level of education achieved and (primary) country of residence.

Age categories		Occupation		Gender	
18–24	11	Employee in private sector	46	Woman	74
25–34	41	Employee in public sector	36	Man	45
35–44	34	Student	16	Non-binary	1
45–54	19	Self-employed	12		
55–64	9	Retired	5	**Country of residence**	
65–74	5	Prefer not to say	4	Americas	3
75+	1	Unemployed	1	Asia	22
				Northern Europe	47
Education level				Central Europe	13
Entry level (Primary education)			1	Southern Europe	35
Level 1–2 (Secondary / High school)			4		
Level 3–5 (Further ed. / College / Apprenticeship, etc.)			21		
Level 6 (Higher education / University - Bachelor)			33		
Level 7 (Higher education / University - Masters)			36		
Level 8 (Higher education / University - PhD)			25		

educational level, a fifth of the respondents had gained a primary or secondary level education, around a quarter had achieved a graduate level education and approximately half held post-graduate degrees.

4.1. Respondents' usage of conventional plastics

To provide context for our results, respondents were asked about the factors that determine plastic product consumption in general (Table 3). The vast majority of respondents chose functionality (91%) and cost (74%) as very important or absolutely essential. Environmental sustainability (58%), convenience (57%), and social sustainability (55%) were also deemed important. Concerning the use of conventional plastics, most of the respondents reported the use of single-use (79%) and durable (83%) plastics on a weekly or daily basis. Overall, a high level of confidence with regard to functionality was reported, with 53% stating that they were somewhat or extremely confident that conventional plastics are fit for purpose. With regards to safety, a mixed picture emerged: 43% of respondents stated that they were somewhat or extremely confident that conventional plastics are safe. Of these responses, 17 attributed confidence to labelling and certification schemes. However, 29% stated that they were (somewhat or extremely) not confident and 28% reported a neutral confidence level. The reasons behind the negative responses were varied, with some subjects admitting a lack of knowledge, others noting bad habits in plastic use or concerns about toxicological safety, and few mentioning production processes. Finally, the use of additives, "general concerns", company reputations, and a lack of alternatives were also mentioned.

4.2. Respondents' utilization of alternative plastics

In order to check for H1, the analysis of responses focused on the differences among the four groups of consumers. Usage is described as how successful this group of consumers had been in replacing conventional plastics, searching for and buying products manufactured from alternative materials.

Overall, around half of the respondents (51%,) stated that they were able to replace conventional plastics by finding alternatives for the products they used (Fig. 2, section a). As would be expected, a significant difference ($p \leq 0.05$) was found when groups were compared. Respondents in group 4 (environmentally conscientious; EC) reported the most success in finding alternatives, with none reporting that they struggle to find, or are not interested in finding, alternatives. In addition to group 4 (EC), only respondents in groups 3 (environmentally galvanized; EG) reported that they had found alternatives for every product they use.

Respondents were then asked how often they sought out alternative plastic products (Fig. 2, section b). Overall, a mixed response was reported. However, when evaluated by group response, significant differences were found ($p \leq 0.05$). Over half of the respondents in groups 2 (environmentally aware; EA; 58%) and 4 (EC; 70%) stated that they sought out alternative plastic products, either "always", "very often" or "sometimes". In contrast, the majority of respondents in group 1 (environmentally indifferent; EI) reported that they "rarely" (40%) or "never" (20%) sought them out.

When asked how often they purchased alternative plastic products (Fig. 2, section c), the majority (81%) of group 4 (EC) selected "always", "sometimes" or "occasionally". This contrasts with the other groups. Group 1 (EI) were the least likely to purchase alternative plastic products, with no respondents selecting "always", and 20% selecting "sometimes" or "occasionally". Groups 2 (EA) and 3 (EG) represented similar results where, respectively, 33% and 28% of respondents selected "sometimes", and 21% and 30% selected "occasionally". Only one respondent in group 2 (EA) selected "always".

Simple descriptive statistics demonstrate that H1 is confirmed, where the environmentally conscientious (EC) subjects included in group 4 are the most active in searching, purchasing and replacing alternatives to conventional plastics.

4.3. Respondents' knowledge about alternative plastics

With regards to H2, most respondents were aware of the terms (recycled, recyclable, biodegradable, and to a lesser extent, degradable, compostable and bioplastic). However, respondents were generally less familiar with the terms bio-based and bioderived. When groups were compared, significant differences were found only for the terms bioderived and compostable ($p \leq 0.05$). In addition, participants were asked to respond to a block of questions designed to compare their confidence level to actual knowledge. No big knowledge gaps were detected: where four-fifths of respondents were able to correctly define bio-based, bio-derived, degradable, compostable, recyclable and recycled. Around two-thirds of participants were able to correctly define biodegradable. Regarding the term bioplastic however, less than a third of the participants who reported that they were "somewhat confident" or "very confident" about the term provided a correct definition. Sixteen respondents thought that bioplastic was interchangeable with bio-based plastic.

Similarly, respondents were comfortable with disposal paths of plastics labelled compostable and biodegradable, with 58% and 50%

Table 3
Descriptive results regarding the factors that determine plastic product consumption, frequency of use (single-use and durable plastic products) and level of confidence with respect to functionality and safety.

Factors	Not important at all	Of little importance	Of average importance	Very important	Absolutely essential
Environ. sustainability	1 *(1%)*	4 *(3%)*	45 *(38%)*	52 *(43%)*	18 *(15%)*
Social sustainability	0 *(0%)*	10 *(8%)*	44 *(37%)*	47 *(39%)*	19 *(16%)*
Cost	0 *(0%)*	2 *(2%)*	29 *(24%)*	69 *(58%)*	20 *(17%)*
Functionality	0 *(0%)*	0 *(0%)*	11 *(9%)*	41 *(34%)*	68 *(57%)*
Convenience	0 *(0%)*	17 *(14%)*	35 *(29%)*	57 *(48%)*	11 *(9%)*
Design / Brand	15 *(13%)*	49 *(41%)*	37 *(31%)*	16 *(13%)*	3 *(0%)*

Frequency of use	Daily	Weekly	Monthly	Seasonally	Yearly	Never
Single-use plastics	39 *(33%)*	56 *(47%)*	16 *(13%)*	4 *(3%)*	3 *(3%)*	2 *(2%)*
Durable plastics	62 *(52%)*	38 *(32%)*	15 *(13%)*	4 *(3%)*	0 *(0%)*	1 *(1%)*

Confidence	Extremely confident	Somewhat confident	Neutral	Somewhat not confident	Extremely not confident
Functionality	17 *(14%)*	47 *(39%)*	41 *(34%)*	12 *(10%)*	3 *(3%)*
Safety	13 *(11%)*	39 *(33%)*	33 *(28%)*	29 *(24%)*	6 *(5%)*

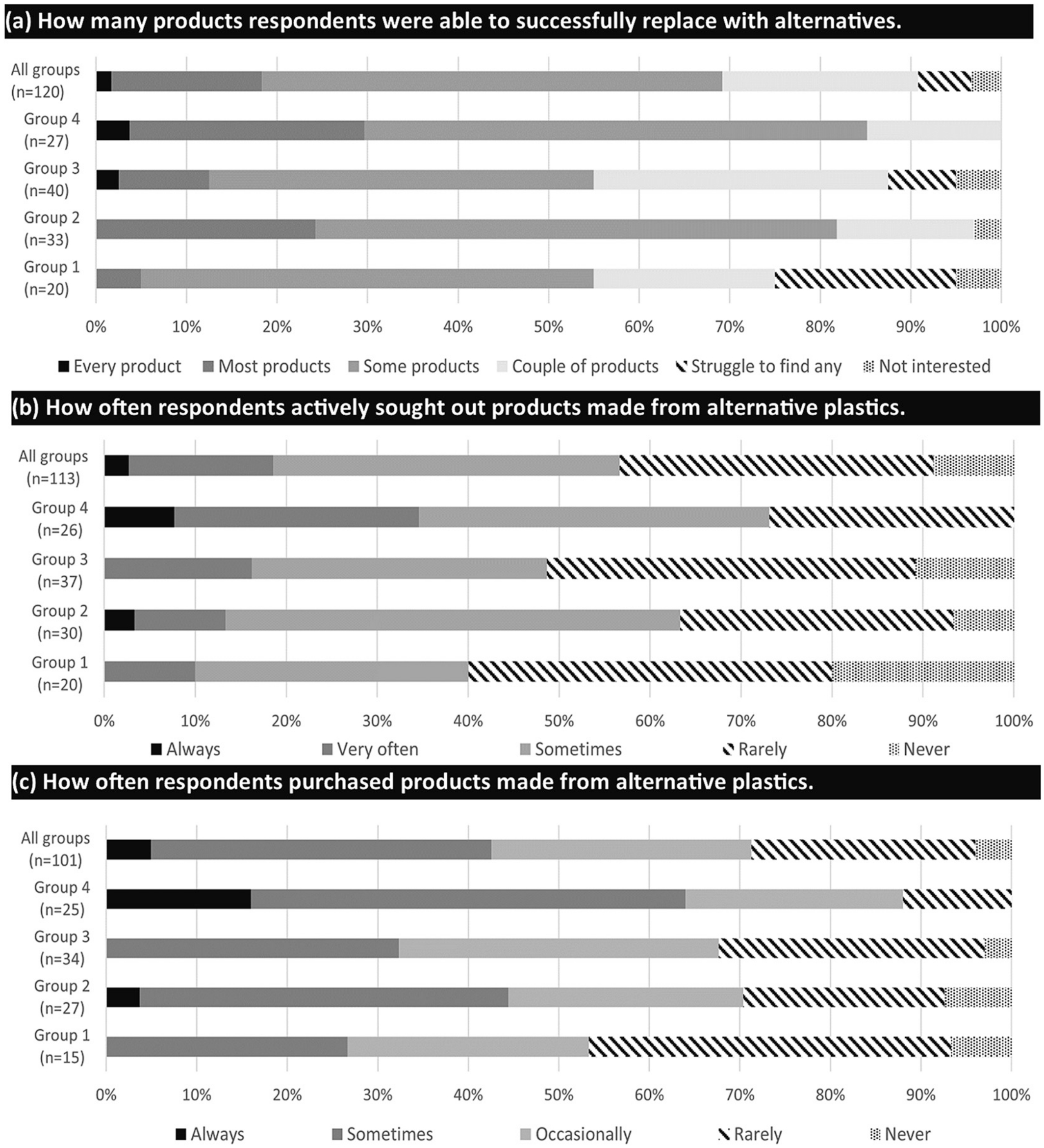

Fig. 2. (A)-(C): Survey responses reported by Groups regarding (A) the replacement of plastic products with alternatives, and the frequency at which respondents (B) seek out and (C) purchase alternative plastic products.

selecting very or quite confident, respectively (Fig. 3). However, qualitative responses reveal that consumers often use these terms interchangeably, such that they think that it is appropriate to include all biodegradable materials within compostable waste. Comparing groups, significant differences were found only concerning the disposal of compostable plastics ($p \leq 0.05$). As would be expected, group 4 (EC) reported a greater level of confidence regarding the correct disposal route for bio-based plastics.

In general, results do not provide sufficient evidence to support the statement that more environmentally conscious subjects know the meaning of technical terms related to alternative plastics and their disposal routes better than respondents across the other groups (H2). Since for both bio-based and bio-derived plastics, a mixed response was reported by all groups with "not so confident" being reported by the majority, we remark that some level of confusion exists among all consumers especially regarding disposal.

An additional interesting qualitative finding emerged when respondents were asked what producers can do to improve confidence levels concerning disposal. The majority of respondents who answered highlighted the importance of clear and explicit instructions, information and/or labels, with nuances to facilitate self-education, improved transparency, and country specificity. Indeed, one respondent made a valid point with regards recyclable plastics: noting that "*Recyclable' means it's technically recyclable but doesn't necessarily correspond with what waste collectors in your area can accept for recycling. In Ireland, for instance, soft plastics are not recycled, but labels on soft plastics will often say 'recyclable', which is technically accurate but misleads consumers and results in contamination of the recycling* stream." This suggests the continued need for whole systems thinking when introducing alternatives within different markets.

4.4. Respondents' expectations about alternative plastics

With regards to H3, the majority of respondents (68%) expect alternatives to perform to the same technical standard as conventional plastics, with 22% reporting a higher level of expectation and 10% reporting a lower level. With respect to environmental performance, the majority of respondents (63%) reported a higher level of expectation when compared with conventional plastics, reiterating the opinion that alternative plastics should be less damaging than conventional plastics

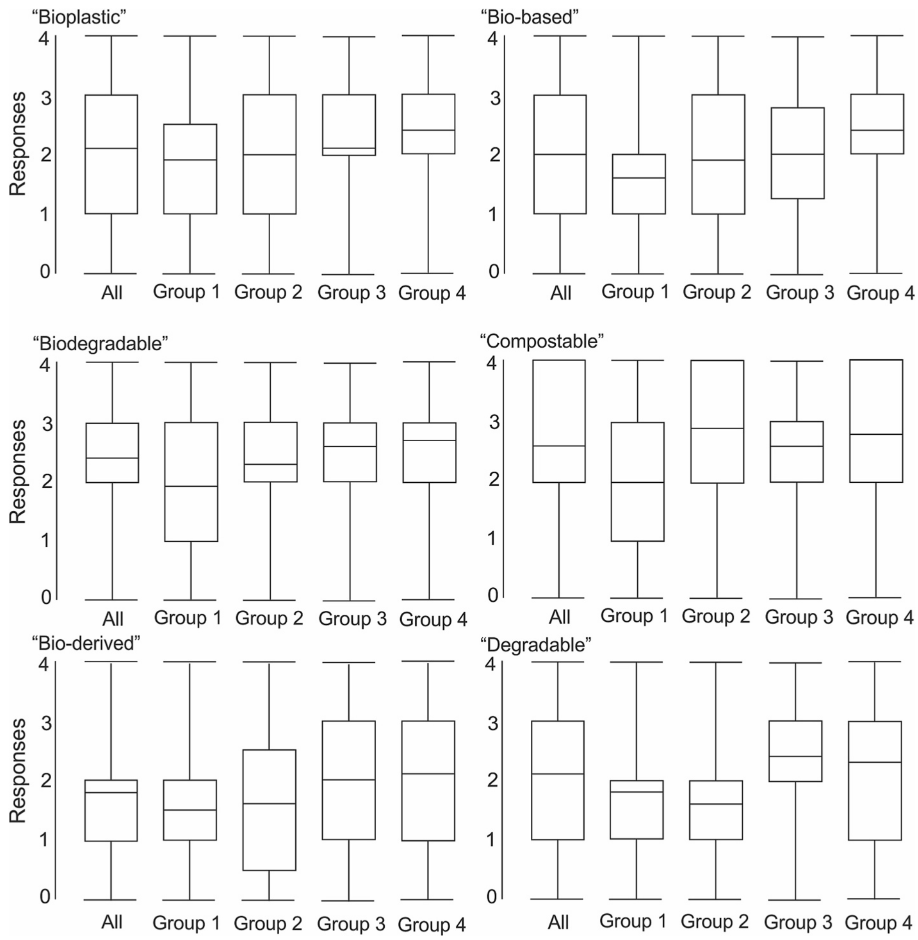

Fig. 3. Confidence level response (0 = Don't know; 1 = Not confident at all; 2 = Not so confident; 3 = Quite confident; 4 = Very confident) regarding disposal of alternative plastics presented as Box (1st Quartile; Mean; 3rd Quartile) and Whisker (Min; Max) plots.

(Table 4). With respect to H3, comparative analysis among groups of respondents indicates that there is insufficient evidence to support the statement regarding technical performance.

With respect to environmental expectations, comparison of responses found a significant difference ($p \leq 0.05$) between the groups. Groups 1 (EI) and 3 (EG) have similar expectations, with 60% and 63% of respondents (respectively) reporting higher expectations. As would be anticipated, group 2 (EA) reported higher expectations (indeed the highest across all groups), where 82% of respondents chose the higher-level option. Interestingly however, group 4 (EC) had the lowest level of expectation, with only 44% of respondents choosing the higher level. Overall, there is insufficient evidence to fully support the H3 statement, while group 2 (EA) had the greatest environmental expectations of alternative plastics, group 4 (EC) reported the lowest.

5. Discussion

Since consumer behavior change is a source of empowerment and innovation for businesses, and thus can promote more sustainable practices in several industries (Kaufman et al., 2021), this study aimed to better understand consumer orientation and behavior towards the uptake of bio-based and biodegradable plastics.

First, results confirmed a high level of conventional plastic consumption (concerning both single-use and durable products), where respondents chose functionality and costs as the most important determining factors for purchase and use. Therefore, technical (i.e., functional) performance of bio-based products should never be lower compared to similar items made of conventional plastics. In relationship to safety aspects, a mixed picture emerged instead due to lack of knowledge, unclear messages regarding labelling and the impact of unreliable consumer habits, including littering. This aspect suggests that bio-based and biodegradable plastics should leverage on scientific evidence and enhance safety features to accent value creation, boost their acceptance and accelerate market development. This is in line with Scarpi et al. (2021) who consider safety, quality, and performance as the major risks for bio-based products purchasing.

Second, in line with similar studies (Edo et al., 2022; Testa et al., 2021), results confirmed that the utilization (i.e., seeking out, purchasing and replacing) of products made from bio-based and biodegradable plastics is higher among consumers with a stronger orientation towards environmental sustainability. Therefore, investigating which elements affect consumer orientation emerged as extremely valuable.

This study found that the positive orientation towards environmental sustainability is not always based on greater levels of knowledge. Overall consumer knowledge was limited when concerning the differentiation among bio-based, bio-derived, degradable, compostable, recyclable and recycled terms. This corresponds with the findings of Klein et al. (2019) and García-Depraect et al. (2021), who argue that the term "bioplastic" – that may also include fossil-based materials – is not easy for the consumer to understand and that it is often thought as interchangeable with the term "bio-based plastic". This is an issue that has already gained traction within the EU policy framework (Philp et al., 2013). Similar level of confusions emerged when confidence concerning disposal routes was assessed. Such poor knowledge regarding disposal supports recommendations with the extant literature (e.g., European Bioplastics [EUBP], 2017; Neves et al., 2020; Ansink et al., 2022) to

Table 4
Respondent's response when asked to compare expected levels of technical and environmental performance of alternative plastics with respect to conventional plastics.

When compared with conventional plastics, level of expectation for alternative plastics (such as bio-based and/or biodegradable plastics) with respect to how…	*n*	Higher level	Same level	Lower level
…well they should technically perform?				
All respondents	120	26 *(22%)*	82 *(68%)*	12 *(10%)*
Group 1 (EI)	20	4 *(20%)*	13 *(65%)*	3 *(15%)*
Group 2 (EA)	33	7 *(21%)*	23 *(70%)*	3 *(9%)*
Group 3 (EG)	40	8 *(20%)*	27 *(68%)*	5 *(13%)*
Group 4 (EC)	27	7 *(26%)*	19 *(70%)*	1 *(4%)*
… environmentally conscious they are?				
All respondents	120	76 *(63%)*	39 *(33%)*	5 *(4%)*
Group 1 (EI)	20	12 *(60%)*	6 *(30%)*	2 *(10%)*
Group 2 (EA)	33	27 *(82%)*	5 *(15%)*	1 *(3%)*
Group 3 (EG)	40	25 *(63%)*	13 *(33%)*	2 *(5%)*
Group 4 (EC)	27	12 *(44%)*	15 *(56%)*	0 *(0%)*

encourage policymakers to introduce harmonized collection schemes across EU countries and guide businesses through the adoption of clear and regulated waste sorting operations.

When considering expectations, this study found that those who are more environmentally conscious did have same-to-increased expectations for alternative materials when compared with conventional plastics. However, when focusing on environmental expectations (the domain where alternative plastics should excel as evidenced by previous results such as the survey of Notaro et al., 2022), the results were mixed. The group of respondents where the value-action gap was the widest (i.e., thought themselves as environmentally conscious but did not generally take part in environmental actions) is the one who reported the greatest expectations. This is driven by the unrealistic expectations this consumer segment has in regard with alternative plastic, at such a point that their intentions are not translated in actions. This aligns with the findings of Falcone and Imbert (2018) who suggest that unrealistic consumer expectations may exacerbate existing challenges within the bioplastic market. Therefore, producers should carefully weigh up their communication to customers as remarked by Blesin et al. (2017).

Incorrect (unrealistic) expectations may negatively impact the uptake of alternative plastics along the value chain. Incorrect expectations may lead businesses, in addition to consumers, to generate misalignment between material characteristics and the intended use in final products (Liliani, 2020). As a consequence, unrealistic expectations may lead to increased consumer skepticism towards company reputation and relative value offer (Chen and Chang, 2013; Filho et al., 2020). Businesses must therefore be careful to consider all these aspects when introducing a new product portfolio that utilize alternative plastics. As pointed out by Ansink et al. (2022), these aspects should be taken into consideration already in the product design in order to reduce the likelihood of economic and motivational rebound effects, both of which have implications for effective circular economy. Indeed, the survey results also support arguments presented by Ansink et al. (2022) and Leal Filho et al. (2022) that consumer confusion regarding the differences between conventional and alternative plastics may result in the incorrect disposal or the shorter life span of these plastics. Ansink et al. (2022) concluded that the use of existing cues, such as logos and symbols, are not sufficient enough to inform or change established behaviors. Wilde and Hermans (2021) also argue that consumers are currently over-exposed to multiple non-transparent labels, which can lead to increased confusion. However, the survey results do dispute the conclusion made by Ansink et al. (2022) that environmental attitudes are not linked to consumers' knowledge on how to dispose plastic waste. Instead, this study found that those consumers labelled as environmentally conscientious (group 4) were more likely to identify the correct disposal route for compostable plastics. This suggests that increased consumer commitment to environmental aspects is associated with knowledge and awareness, and both may contribute to the purchasing of alternative plastics.

If a greater level of consumer knowledge is required to boost green consumerism, knowledge needs to be promoted through clear and concise quantitative information that can be provided by standards or certification schemes. As remarked by Purkus et al. (2018) and Falcone and Imbert (2019), standards and certifications may tackle the complexity and uncertainty associated to bio-based plastics and create the conditions to ensure a level playing field between bio-based and conventional products. By developing information, measurement and quality standards, issues due to asymmetric information between supply and demand can be overcome. However, it is also recommended a balanced approach to standardization because knowledge and technical features are continuously developing, and standards should be harmonized. In other terms, policymakers and standard setters should strongly rely on schemes and frameworks that may offer comprehensive information on multiple aspects (Purkus et al., 2018; Falcone and Imbert, 2019).

Results offer the possibility to infer reflections and implications for policy, the market and waste management. Indeed, the increasing interest towards sustainability disclosure, combined with the insufficient consumers' knowledge and understanding regarding the term "bioplastic" and similarities has implications across the value chain. As highlighted by Neves et al. (2020), this trend can impact upstream processes - whereby bioplastics producers and users are spurred to adopt claims that are not always supported by scientific evidence, but also downstream stages such as consumption and disposal where unclear communication makes proper product use and correct waste collection challenging, thus causing complications for municipalities, waste management companies and recycling plants. It can also reduce consumer confidence, where self-efficacy to make sustainability-related judgements is restricted (Neves et al., 2020). In this regard, the Green Claim Directive has the potential to empower consumers against greenwashing.

Furthermore, more strict policy instruments such as the Single-Use Plastic Directive and Packaging and Packaging Waste Regulation could include specific sections on the alternative to market restriction and reduction consumption measures, thus supporting business to envision radical transformation. The introduction of choice editing (an option identified by survey respondents) could also be explored. Choice editing is the process whereby products that do not uphold consumer and/or political expectations regarding technical performance, safety and environmental aspects are removed from the marketplace. However, consequences for consumer sovereignty, as well as ideological implications and pragmatic factors would need to be addressed (Gunn, 2011).

6. Conclusion

Acknowledging the growing pressure posed by the use of conventional plastics, this study investigates consumer orientation towards environmental sustainability and its effect on the uptake of alternative materials, inlcuding bio-based and biodegradable plastics. Most research has investigated technological, chemical and eco-toxicity issues, without giving great attention to the social and economic aspects that may advance bioeconomy. When addressed, consumers studies pose emphasis on green purchasing behaviors, with little focus on the effects of consumers' decisions along the entire value chain. This study sets out to foster a greater understanding of the implications of consumer environmental self-identity and actions (influenced by differing expectations and levels of knowledge) on the use of products made from bio-based and biodegradable plastics.

The results suggest that potential barriers to the uptake of these alternative plastics are caused by continued confusion, unrealistic expectations, and the value-action gap. While these barriers are visible at the consumer level, they have wider implications across the entire value chain. As such, it is imperative that the existing barriers are addressed holistically, where solutions employed by policymakers, marketplace actors and the waste management sector should seek to (in combination) drive the probability of consumers undertaking positive responsible actions. Enhanced public engagement, togheter with clearer long-term ambitions, is a key mechanism for this.

This paper has some limitations. Firstly, whereas the respondent profile indicated representation from a set of countries, the response rate ($n = 120$) means that specific findings cannot be generalized. Indeed, this somewhat restricted the potential discussion on the influence of national legislative framework and cultural system on context-dependent findings. Secondly, the approaches taken in participant recruitment, and the procedures used for the online survey, may have restricted mechanisms for respondents to ask clarification questions, potentially influencing responses through misunderstanding. Finally, the self-reporting style, plus the inability of the researchers to validate responses, means that there can be no assurances that respondents provided information which may be deemed as completely accurate.

Notwithstanding these limitations, this study provides a welcome contribution to the literature by including a multi-country perspective as suggested by Herbes et al. (2018). In contrast, comparable studies have tended to focus on single nations such as Germany (Klein et al., 2019), Spain (Gutiérrez Taño et al., 2021), USA (Confente et al., 2020) and the Netherlands (Lynch et al., 2017). More importantly, it frames consumers environmental orientation in a way that considers both self-identity and actions, overcoming the disparity between attitudes and behaviors of previous research that has focused on either attitudes (Confente et al., 2020; Scarpi et al., 2021; Sijtsema et al., 2016) or purchase (Gutiérrez Taño et al., 2021; Klein et al., 2019; Notaro et al., 2022). A different perspective to the literature is also presented in this study, which investigates the influence of consumer orientation towards environmental sustainability on purchasing while taking into account the role of knowledge and expectations.

The implications of this study are two-fold. First, the findings have shown that regardless their orientation towards environmental sustainability, all groups of consumers still struggle to understand the underlying differences between bio-based sourcing and biodegradability, and this has ramifications for the purchase of products made from these materials, consumer satisfaction and correct disposal. The policy implication is that actors across the value chain, in particular policy makers and producers, should try to address this potential area of confusion. By doing so, actors can contribute to wider objectives of current EU policy included within the EU Green Deal, EU Plastics Strategy, the Bioeconomy Strategy and the Circular Economy Action Plan. Furthermore, the study suggests that improvements of communication schemes and educational initiatives should be considered when promoting the uptake of alternative plastics.

Second, the findings presented here support the consensus that consumers who are environmentally conscientious will already seek out and purchase products made from alternative materials. On the contrary, those that do not think themselves to be environmentally aware do not generally seek out these products, thereby presenting a disengaged consumer segment. As such, to increase uptake of products made from alternative materials beyond the niche eco-consumer, producers need to find new ways of attracting a wider consumer base. The practical implication is that producers should focus on reliable and transparent communication about environmental aspects, technical attributes and where possible leveraging future cost effectiveness. Admittedly the latter, may need wider support from policy makers to reduce the cost of these materials and help business investments in the transition towards the bioeconomy. In this relation, the Circular Bio-Based Europe Joint Undertaking public-private partnership (a €2 billion partnership between the EU and the Bio-based Industries Consortium aiming to funds projects on competitive circular bio-based industries) represents an intriguing opportunity to boost market deployment. As one of the pillars of the climate agenda, bioeconomy also covers a pivotal role in the EU Sustainable Finance Framework and the EU Taxonomy that can work as accelerators for sustainable economic activities as they will ultimately favor private investments in green projects.

With respect to future research, linkages between confusion, unrealistic expectations, and the value-action gap could be explored further, specifically their impact on the disposal of alternative plastics. In addition, academics, in collaboration with other value chain actors, could seek to improve consumer acceptance by empirically assessing the role and success of interventions (such as choice editing or mechanisms to improve the clarity and accessibility of information) through consumer engagement activities.

Funding

This research was completed as part of the BIO-PLASTICS EUROPE project, funded by the Horizon 2020 Framework Programme of the European Union, Grant Agreement N° 860407.

Declaration of competing 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.

Data availability

The data that has been used is confidential.

Acknowledgements

This work has received funding from the European Union's Horizon 2020 - Research and Innovation Framework Programme through the research project BIO-PLASTICS EUROPE, under grant agreement No. 860407.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crsust.2024.100246.

References

Ahmed, T., Shahid, M., Azeem, F., Rasul, I., Shah, A.A., Noman, M., Hameed, A., Manzoor, N., Manzoor, I., Muhammad, S., 2018. Biodegradation of plastics: current scenario and future prospects for environmental safety. Environ. Sci. Pollut. Res. 25, 7287–7298. https://doi.org/10.1007/s11356-018-1234-9.

Ali, S.S., Abdelkarim, E.A., Elsamahy, T., Al-Tohamy, R., Li, F., Kornaros, M., Sun, J., 2023. Bioplastic production in terms of life cycle assessment: A state-of-the-art review. Environ. Sci. Ecotechnol. 100254.

Amasawa, E., Yamanishi, T., Nakatani, J., Hirao, M., Sato, S., 2021. Climate change implications of bio-based and marine-biodegradable plastic : evidence from poly (3-

hydroxybutyrate-co-3-hydroxyhexanoate). Environ. Sci. Technol. 55 (5), 3380–3388.

Ansink, E., Wijk, L., Zuidmeer, F., 2022. No clue about bioplastics. Ecol. Econ. 191, 107245 https://doi.org/10.1016/j.ecolecon.2021.107245.

Badia, J.D., Ribes-Greus, A., 2016. Mechanical recycling of polylactide, upgrading trends and combination of valorization techniques. Eur. Polym. J. 84, 22–39. https://doi.org/10.1016/j.eurpolymj.2016.09.005.

Barbarossa, C., De Pelsmacker, P., Moons, I., 2017. Personal values, green self-identity and electric car adoption. Ecol. Econ. 140, 190–200.

Barbir, J., Leal Filho, W., Salvia, A.L., Fendt, M.T.C., Babaganov, R., Albertini, M.C., Bonoli, A., Lackner, M., Müller de Quevedo, D., 2021. Assessing the levels of awareness among European citizens about the direct and indirect impacts of plastics on human health. Int. J. Environ. Res. Public Health 18, 3116. https://doi.org/10.3390/ijerph18063116.

Bishop, G., Styles, D., Lens, P.N.L., 2020. Recycling of European plastic is a pathway for plastic debris in the ocean. J. Env. Int. 142, 105893 https://doi.org/10.1016/j.envint.2020.105893.

Bishop, G., Styles, D., Lens, P.N., 2021. Environmental performance comparison of bioplastics and petrochemical plastics: a review of life cycle assessment (LCA) methodological decisions. Resour. Conserv. Recycl. 168, 105451.

Blesin, J.M., Jaspersen, M., Möhring, W., 2017. Boosting plastics' Image? Communicative challenges of innovative bioplastics. E-plastory-Journal of Historic Polymeric Materials, Plastics Heritage and History, p. 2.

Camilleri, A.R., Larrick, R.P., Hossain, S., Patino-Echeverri, D., 2019. Consumers underestimate the emissions associated with food but are aided by labels. Nat. Clim. Chang. 9 (1), 53–58.

Carrington, M.J., Neville, B., Whitwell, G., 2010. Why ethical consumers don't walk their talk: towards a framework for understanding the gap between the ethical purchase intentions and actual buying behaviour of ethically minded consumers. J. Bus. Ethics 97, 139–158.

Chen, Y.-S., Chang, C.-H., 2013. Greenwash and green trust: the mediation effects of green consumer confusion and green perceived risk. J. Bus. Ethics 114, 489–500. https://doi.org/10.1007/s10551-012-1360-0.

Chen, L., Pelton, R.E., Smith, T.M., 2016. Comparative life cycle assessment of fossil and bio-based polyethylene terephthalate (PET) bottles. J. Clean. Prod. 137, 667–676.

Chwialkowska, A., Bhatti, W.A., Glowik, M., 2020. The influence of cultural values on pro-environmental behavior. J. Clean. Prod. 268, 122305.

Claudy, M., Peterson, M., 2022. Sustainability: understanding consumer behavior in a circular economy. In: Kahle, L.R. (Ed.), APA Handbook of Consumer Psychology. https://doi.org/10.1037/0000262-015.

Confente, I., Scarpi, D., Russo, I., 2020. Marketing a new generation of bio-plastics products for a circular economy: the role of green self-identity, self-congruity, and perceived value. J. Bus. Res. 112, 431–439. https://doi.org/10.1016/j.jbusres.2019.10.030.

Cristóbal, J., Albizzati, P.F., Giavini, M., Caro, D., Manfredi, S., Tonini, D., 2023. Management practices for compostable plastic packaging waste: impacts, challenges and recommendations. Waste Manag. 170, 166–176.

D'Adamo, I., Falcone, P.M., Imbert, E., Morone, P., 2020. A socio-economic indicator for EoL strategies for bio-based products. Ecol. Econ. 178, 106794.

Dean, M., Raats, M.M., Shepherd, R., 2012. The role of self-identity, past behavior, and their interaction in predicting intention to purchase fresh and processed organic food 1. J. Appl. Soc. Psychol. 42 (3), 669–688.

Department for Business, Energy & Industrial Strategy [BEIS], 2021. UK Emissions Trading Scheme (UK ETS): Monitoring and Reporting Biomass in Installations. UK GOV. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033859/uk-ets-monitoring-reporting-biomass-installations.pdf (accessed 02 September 2022).

Döhler, N., Wellenreuther, C., Wolf, A., 2022. Market dynamics of biodegradable bio-based plastics: projections and linkages to European policies. J. Bio Econ. 2, 100028 https://doi.org/10.1016/j.bioeco.2022.100028.

Edo, C., Fernández-Piñas, F., Rosal, R., 2022. Microplastics identification and quantification in the composted organic fraction of municipal solid waste. J. Sci Tot Env. 813, 151902 https://doi.org/10.1016/j.scitotenv.2021.151902.

European Bioplastics [EUBP], 2017. Recycling and Recovery: End of Life Options for Bioplastics. https://docs.european-bioplastics.org/publications/pp/EUBP_PP_End-of-life.pdf (accessed 03 September 2022).

European Bioplastics [EUBP], 2018. What are Bioplastics? https://www.european-bioplastics.org/bioplastics/ (accessed 03 September 2022).

European Commission [EC], 2018. A European Strategy for Plastics in a Circular Economy. https://environment.ec.europa.eu/strategy/plastics-strategy_en (accessed 01 September 2022).

European Commission [EC], 2020. A Sustainable Bioeconomy for Europe: Strengthening the Connection Between Economy, Society and the Environment: Updated Bioeconomy Strategy. Directorate-General for Research and Innovation https://data.europa.eu/doi/10.2777/792130 (accessed 01 September 2022).

European Commission [EC], 2020b. A new Circular Economy Action Plan For a cleaner and more competitive Europe. https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en (accessed 01 September 2022).

European Commission [EC], 2020c. A European Green Deal: Striving to be the First Climate-Neutral Continent. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en (accessed 01 September 2022).

European Union [EU], 2019. Directive (EU) 2019/904 OF the European Parliament and of the Council of 5 June 2019 on the Reduction of the Impact of Certain Plastic Products on the Environment. http://data.europa.eu/eli/dir/2019/904/oj (accessed 01 September 2022).

Falcone, P.M., 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. https://doi.org/10.3390/su10041031.

Falcone, P.M., Imbert, E., 2019. Tackling uncertainty in the bio-based economy. Int. J. Standardizat. Res. 17 (1), 74–84.

Filho, W.L., Salvia, A.L., Bonoli, A., Saari, U.A., Voronova, V., Klõga, M., Kumbhar, S.S., Olszewski, K., De Quevedo, D.M., Barbir, J., 2020. An assessment of attitudes towards plastics and bioplastics in Europe. J. Sci Tot Env. 755, 142732. https://doi.org/10.1016/j.scitotenv.2020.142732.

Filiciotto, L., Rothenberg, G., 2021. Biodegradable plastics: standards, policies, and impacts. ChemSusChem 14, 56–72. https://doi.org/10.1002/cssc.202002044.

Findrik, E., Meixner, O., 2023. Drivers and barriers for consumers purchasing bioplastics–a systematic literature review. J. Clean. Prod. 137311.

Fletcher, C.A., Niemenoja, K., Hunt, R., Adams, J., Dempsey, A., Banks, C.E., 2021. Addressing stakeholder concerns regarding the effective use of bio-based and biodegradable plastics. Resources 10, 95. https://doi.org/10.3390/resources10100095.

Flynn, R., Bellaby, P., Ricci, M., 2009. The 'value-action gap' in public attitudes towards sustainable energy: the case of hydrogen energy. Sociol. Rev. 57, 159–180. https://doi.org/10.1111/j.1467-954X.2010.01891.x.

Foschi, E., Aureli, S., Paletta, A., 2023. Linking bioeconomy, circular economy, and sustainability: trends, gaps and future orientation in the bio-based and biodegradable plastics industry. Eur. J. Soc. Impact Circul. Econom. 4 (2), 16–31.

Friedman, H.H., Amoo, T., 1999. Rating the rating scales. J. Mark. Manag. 9, 114–123. https://ssrn.com/abstract=2333648.

Gao, L., Wheeler, S.C., Shiv, B., 2009. The "shaken self": Product choices as a means of restoring self-view confidence. J. Consum. Res. 36 (1), 29–38.

García-Depraect, O., Bordel, S., Lebrero, R., Santos-Beneit, F., Börner, R.A., Börner, T., Muñoz, R., 2021. Inspired by nature: microbial production, degradation and valorization of biodegradable bioplastics for life-cycle-engineered products. Biotechnol. Adv. 53, 107772 https://doi.org/10.1016/j.biotechadv.2021.107772.

Gilg, A., Barr, S., Ford, N., 2005. Green consumption or sustainable lifestyles? Identifying the sustainable consumer. Futures 37 (6), 481–504.

Gunn, M., 2011. The potential for retailers to practice 'choice editing' as a policy tool for sustainable consumption. Int. J. Retail Distrib. Manag. 42 (6), 464–481. https://doi.org/10.1108/IJRDM-12-2012-0110.

Gutiérrez Taño, D., Hernández Méndez, J., Díaz-Armas, R., 2021. An extended theory of planned behaviour model to predict intention to use bioplastic. J. Soc. Mark. 12, 5–28. https://doi.org/10.1108/JSOCM-09-2020-0190.

Gutierrez Tano, D., Hernandez Mendez, J., Díaz-Armas, R., 2022. An extended theory of planned behaviour model to predict intention to use bioplastic. J. Soc. Mark. 12 (1), 5–28.

Harding, K.G., Dennis, J.S., von Blottnitz, H., Harrison, S.T.L., 2007. Environmental analysis of plastic production processes: comparing petroleum-based polypropylene and polyethylene with biologically based poly-β-hydroxybutyric acid using life cycle analysis. J. Biotechnol. https://doi.org/10.1016/j.jbiotec.2007.02.012.

Hares, A., Dickinson, J., Wilkes, K., 2010. Climate change and the air travel decisions of UK tourists. J. Transp. Geogr. 18 (3), 466–473.

Herbes, C., Beuthner, C., Ramme, I., 2018. Consumer attitudes towards biobased packaging – a cross-cultural comparative study. J. Clean. Prod. 194, 203–218. https://doi.org/10.1016/j.jclepro.2018.05.106.

Herrmann, C., Rhein, S., Sträter, K.F., 2022. Consumers' sustainability-related perception of and willingness-to-pay for food packaging alternatives. Resour. Conserv. Recycl. 181, 106219.

Hosta, M., Zabkar, V., 2021. Antecedents of environmentally and socially responsible sustainable consumer behavior. J. Bus. Ethics 171 (2), 273–293.

Kang, J.H., Kang, S.W., Kim, W.J., Kim, D.H., Im, S.W., 2022. Anaerobic co-digestion of bioplastics and food waste under mesophilic and thermophilic conditions: synergistic effect and biodegradation. Fermentation 8 (11), 638.

Kaufman, S., Saeri, A., Raven, R., Malekpour, S., Smith, L., 2021. Behaviour in sustainability transitions: a mixed methods literature review. Environ. Innov. Soc Transit. 40, 586–608. https://doi.org/10.1016/j.eist.2021.10.010.

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

Kostadinova, E., 2016. Sustainable consumer behavior: literature overview. Econom. Alternat. 2, 224–234.

Leal Filho, W.L., Barbir, J., Abubakar, I.R., Paço, A., Stasiskiene, Z., Hornbogen, M., Christin Fendt, M.T., Voronova, V., Klõga, M., 2022. Consumer attitudes and concerns with bioplastics use: an international study. PLoS One 17, e0266918. https://doi.org/10.1371/journal.pone.0266918.

Liliani, Tjahjono, B., 2020. A conceptual framework for a dyadic supplier-customer co-innovation of bioplastic packaging. Proced. CIRP 90, 339–343. https://doi.org/10.1016/j.procir.2020.01.056.

Lynch, D.H.J., Klaassen, P., Broerse, J.E.W., 2017. Unraveling Dutch citizens' perceptions on the bio-based economy: the case of bioplastics, bio-jet fuels and small-scale bio-refineries. Ind. Crop. Prod. 106, 130–137. https://doi.org/10.1016/j.indcrop.2016.10.035.

Maitre-Ekern, E., Dalhammar, C., 2019 Jun. Towards a hierarchy of consumption behaviour in the circular economy. Maastricht J. Eur. Comparat. Law 26 (3), 394–420.

Martin, M., Røyne, F., Ekvall, T., Moberg, Å., 2018. Life Cycle Sustainability Evaluations of Bio-Based Value Chains: Reviewing the Indicators from a Swedish Perspective. Multidisciplinary Digital Publishing Institute, Switzerland. https://doi.org/10.3390/su10020547.

Mehta, P., Chahal, H.S., 2021. Consumer attitude towards green products: revisiting the profile of green consumers using segmentation approach. Manag. Environ. Qual. 32 (5), 902–928.
Morone, P., Caferra, R., D'Adamo, I., Falcone, P.M., Imbert, E., Morone, A., 2021. Consumer willingness to pay for bio-based products: do certifications matter? Int. J. Prod. Econ. 240, 108248.
Nanda, S., Patra, B.R., Patel, R., Bakos, J., Dalai, A.K., 2022. Innovations in applications and prospects of bioplastics and biopolymers: a review. Environ. Chem. Lett. 20 (1), 379–395.
Neves, A.C., Moyne, M.M., Eyre, C., Casey, B.P., 2020. Acceptability and societal impact of the introduction of Bioplastics as novel environmentally friendly packaging materials in Ireland. Clean Technol. 2 https://doi.org/10.3390/cleantechnol2010009.
Newton, J.D., Tsarenko, Y., Ferraro, C., Sands, S., 2015. Environmental concern and environmental purchase intentions: the mediating role of learning strategy. J. Bus. Res. 68 (9), 1974–1981.
Niaounakis, M., 2019. Recycling of biopolymers – the patent perspective. Eur. Polym. J. 114, 464–475. https://doi.org/10.1016/j.eurpolymj.2019.02.027.
Notaro, S., Elisabetta, L., Alessandro, P., 2022. Behaviours and attitudes of consumers towards bioplastics: an exploratory study in Italy. J. For. Sci. 2022 (68), 121–135.
Paletta, A., Leal Filho, W., Balogun, A.L., Foschi, E., Bonoli, A., 2019. Barriers and challenges to plastics valorisation in the context of a circular economy: case studies from Italy. J. Clean. Prod. 241, 118149.
Philp, J.C., Bartsev, A., Ritchie, R.J., Baucher, M.-A., Guy, K., 2013. Bioplastics science from a policy vantage point. New Biotechnol. 30, 635–646. https://doi.org/10.1016/j.nbt.2012.11.021.
Prata, J.C., Silva, A.L.P., Duarte, A.C., Rocha-Santos, T., 2021. The road to sustainable use and waste management of plastics in Portugal. Front. Environ. Sci. Eng 16, 5. https://doi.org/10.1007/s11783-021-1439-x.
Purkus, A., Hagemann, N., Bedtke, N., Gawel, E., 2018. Towards a sustainable innovation system for the German wood-based bioeconomy: implications for policy design. J. Clean. Prod. 172, 3955–3968.
Rosenboom, J.-G., Langer, R., Traverso, G., 2022. Bioplastics for a circular economy. Nat. Rev. Mater. 7, 117–137. https://doi.org/10.1038/s41578-021-00407-8.
Scarpi, D., Russo, I., Confente, I., Hazen, B., 2021. Individual antecedents to consumer intention to switch to food waste bioplastic products: a configuration analysis. Ind. Mark. Manag. 93, 578–590. https://doi.org/10.1016/j.indmarman.2020.09.006.
Schneider, J., Hall, J., 2011. Why most product launches fail. Harv. Bus. Rev. 89 (4), 21–23.
Shevchenko, T., Saidani, M., Ranjbari, M., Kronenberg, J., Danko, Y., Laitala, K., 2023. Consumer behavior in the circular economy: developing a product-centric framework. J. Clean. Prod. 384, 135568.
Sijtsema, S.J., Onwezen, M.C., Reinders, M.J., Dagevos, H., Partanen, A., Meeusen, M., 2016. Consumer perception of bio-based products—an exploratory study in 5 European countries. NJAS-Wageningen J. Life Sci. 77, 61–69.
Sparks, P., Shepherd, R., 1992. Self-Identity and the Theory of Planned Behavior: Assesing the Role of Identification with "Green Consumerism". Soc. Psychol. Q. 55 (4), 388–399.
Spierling, S., Röttger, C., Venkatachalam, V., Mudersbach, M., Herrmann, C., Endres, H.-J., 2018. Bio-based plastics – a building block for the circular economy? Proced. CIRP 69, 573–578. https://doi.org/10.1016/j.procir.2017.11.017.
Stasiškienė, K., Barbir, J., Draudvilienė, L., Chong, Z.K., Kuchta, K., Voronova, V., Filho, W.L., 2022. Challenges and strategies for bio-based and biodegradable plastic waste Management in Europe. Sustainability 14 (24), 16476. https://doi.org/10.3390/su142416476.
Testa, F., Iovino, R., Iraldo, F., 2020. The circular economy and consumer behaviour: the mediating role of information seeking in buying circular packaging. Bus. Strateg. Environ. 29 (8), 3435–3448.
Testa, F., Di Iorio, V., Cerri, J., Pretner, G., 2021. Five shades of plastic in food: which potentially circular packaging solutions are Italian consumers more sensitive to. Resour. Conserv. Recycl. 173, 105726 https://doi.org/10.1016/j.resconrec.2021.105726.
Trivedi, R.H., Patel, J.D., Acharya, N., 2018. Causality analysis of media influence on environmental attitude, intention and behaviors leading to green purchasing. J. Clean. Prod. 196, 11–22.
Uehara, T., Nakatani, J., Tsuge, T., Asari, M., 2023. Consumer preferences and understanding of bio-based and biodegradable plastics. J. Clean. Prod. 417, 137979.
Van Tonder, E., Fullerton, S., De Beer, L.T., Saunders, S.G., 2023. Social and personal factors influencing green customer citizenship behaviours: the role of subjective norm, internal values and attitudes. J. Retail. Consum. Serv. 71.
Vethaak, A.D., Legler, J., 2021. Microplastics and human health. Science 371 (6530), 672–674.
Vidal-Ayuso, F., Akhmedova, A., Jaca, C., 2023. The circular economy and consumer behaviour: literature review and research directions. J. Clean. Prod. 137824.
White, K., Habib, R., Hardisty, D.J., 2019. How to SHIFT consumer behaviors to be more sustainable: a literature review and guiding framework. J. Mark. 83 (3), 22–49.
Wilde, K., Hermans, F., 2021. Innovation in the bioeconomy: perspectives of entrepreneurs on relevant framework conditions. J. Clean. Prod. 314, 127979.
Zhao, P., Rao, C., Gu, F., Sharmin, N., Fu, J., 2018. Close-looped recycling of polylactic acid used in 3D printing: an experimental investigation and life cycle assessment. J. Clean. Prod. 197, 1046–1055. https://doi.org/10.1016/j.jclepro.2021.127979.
Zheng, J., Suh, S., 2019. Strategies to reduce the global carbon footprint of plastics. Nat. Clim. Chang. 9, 374–378. https://doi.org/10.1038/s41558-019-0459-z.
Zwicker, M.V., Brick, C., Gruter, G.J.M., van Harreveld, F., 2021. (not) doing the right things for the wrong reasons: an investigation of consumer attitudes, perceptions, and willingness to pay for bio-based plastics. Sustainability 13 (12), 6819.