Science of the Total Environment 755 (2021) 142732

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

An assessment of attitudes towards plastics and bioplastics in Europe

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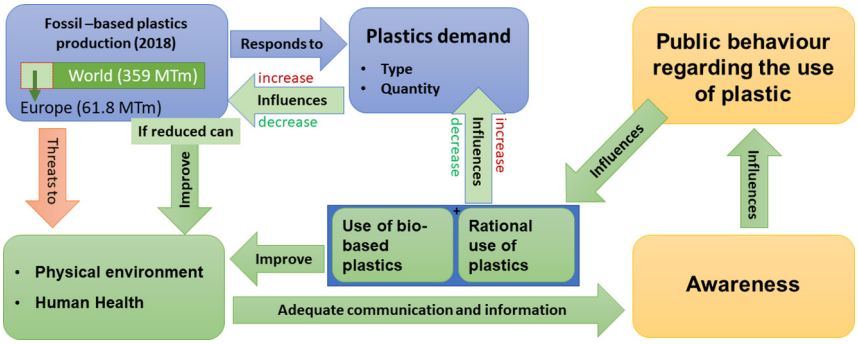
HIGHLIGHTS

- Plastic use and inefficient plastic disposal pose a serious threat to the physical environment and to human health.
- Many Europeans are aware of the problem and segregate and properly dispose plastics.
- Packaging is the most frequent modality of plastic use.
- Even though a positive inclination towards using bioplastic materials exists, their limited availability poses a problem.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 21 July 2020
Received in revised form 18 September 2020
Accepted 20 September 2020
Available online 6 October 2020

Editor: Thomas Kevin V

Keywords:
Plastics
Bioplastics
Assessment
Europe
Environment

ABSTRACT

Over the last 50 years, conventional fossil-based plastics have become an integral part of our everyday lives. Apart from their low production costs, this is due to a number of their unique properties, including durability, strength, lightness, electrical and thermal insulation, resistance to chemicals and corrosion. The production of plastics has increased from 1.5 million metric tons in 1950 to 359 million metric tons in 2018. Of this total, 61.8 million metric tons were produced in Europe. There are various problems associated with plastic use and disposal that pose a serious threat to both the physical environment and human health. Since public behaviour plays a key role when it comes to the use of plastic, this paper reports on a study that focused on an assessment of attitudes towards plastics and bioplastics in Europe. The results showed that packaging is the most frequent modality of plastic used among participants. In addition, majority of participants are aware that plastic waste can affect environment and human health and therefore segregate and properly dispose plastics. Also, even though most respondents were aware of the environmental problems related to plastic use and showed a positive inclination towards using bioplastic materials, their limited availability and lack of relevant information about bioplastics pose a problem for wider use. Departing from the assumption that the public attitude is a determining factor in the consumption of plastics as a whole and bioplastics in particular, this paper also sheds some light on the current situation, identifying some trends and information gaps which should be addressed in order to encourage a more rational use of plastics in Europe.

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https://doi.org/10.1016/j.scitotenv.2020.142732
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1. Introduction

Plastics are synthetic or semi-synthetic organic polymers that are lightweight, strong, durable and low cost (Van Eygen et al., 2017). Due to these key characteristics, they have become an integral part of human everyday life over the last 50 years. The term 'plastics' covers a wide range of synthetic polymeric materials delivered from fossil hydrocarbons, such as polyethylene terephthalate (PET or PETE), high-density polyethylene (HDPE), polyvinyl chloride (PVC), low-density polyethylene (LDPE), polypropylene (PP) or polystyrene (PS), and are designed to meet very different needs of thousands of end products. According to Bourguignon (2017), plastic materials can be classified into various types that are commonly grouped into three broad categories based on their physical characteristics: 1) thermosets (hard plastics that cannot be re-melted and reshaped), 2) thermoplastics (that can be re-melted back into a liquid and reshaped or recycled repeatedly) and 3) elastomers (soft elastic plastics).

The development of the plastics industry has made it possible to satisfy the material needs of the world's growing population, but it needs to be considered that conventional plastic production is based on fossil fuels. Since the applications of plastics are extensive, the production of plastics has been showing a continuous growth and is expected to double in the next 20 years (World Economic Forum, 2016; Gu et al., 2017). Approximately 360 million tons of plastics were produced in 2018, whereas 18.5% of it was produced in Europe (PlasticsEurope, 2019). Fig. 1 describes the global production of plastics.

The plastics industry is in constant development, with technology evolving in response to ever-changing demand (BIO Intelligence Service, 2011). Fig. 2 illustrates the various uses of plastics to date, a trend which explains their wide presence in our daily lives.

Even though the use of plastic has many advantages, plastic leakage into the environment is currently an issue of increasing importance (Chae and An, 2018; Dilkes-Hoffman et al., 2019; Henderson and Green, 2020). Apart from direct landscape problems, plastic pollution (particularly from microplastics) in soil, marine and freshwater ecosystems causes serious problems to living organisms and may endanger human health (Henderson and Green, 2020; Leal Filho et al., 2019; Luo et al., 2019; Prata et al., 2020; Shen et al., 2020). Collection and proper management of plastic waste is at present far from perfect, and around 5–13 million tons of plastic end up in the ocean every year (Geyer et al., 2017; Jambeck et al., 2015). In such a way the durability of plastics, that makes it such an attractive material, turns into a problem, since they are highly resistant to degradation in an open environment.

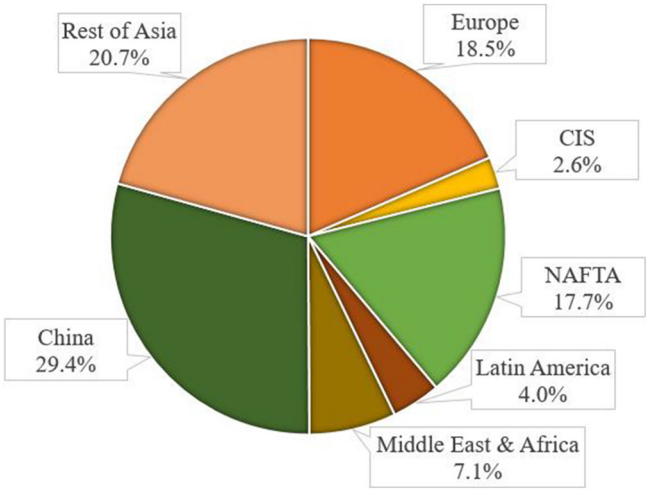

Fig. 1. Global production of plastics* (CIS-Commonwealth and Independent States; NAFTA-North American Free Trade Agreement). *Includes thermoplastics, polyurethanes, thermosets, elastomers, adhesives, coatings and sealants and PP-fibers. Not included PET-, PA- and polyacryl-fibers.
Source: Plastics Europe Market Research Group (PEMRG) (2020) distribution of global plastics production. PEMRG, Berlin.

Bioplastics, which can be bio-based and/or biodegradable are promising to address many environmental concerns. Bio-based plastics are made from biomass (e.g., cellulose, starch, lignin and many others). Some of the bio-based plastics are able to natural degrade in environment into natural harmless substances, whereas some of it require special conditions. The global bioplastics production shows continuous growth over the last years. However bioplastics still represent a very small share of the market (European Bioplastic, 2020a).

According to Dilkes-Hoffman et al. (2019), there is a scarce number of published articles, which address public attitudes towards the environmental impact of used plastic products. Therefore, the main aim of the current research is to investigate some of the main trends on plastic consumption, hence offering a better understanding of the effects of plastic pollution to the environment, and the problems related to plastic use as perceived by consumers. Furthermore, the extent of current efforts on how to reduce plastic consumption was assessed. Special attention was paid to an analysis of the awareness of citizens towards bioplastics, its usage and environmental impacts.

2. Public awareness on plastics and the environment

The perceived seriousness of the environmental risks caused by plastic pollution has increased in society in the past two decades, due to its growing and uncontrolled presence in the environment (Syberg et al., 2018). However, because of existing social practices, the use and production of plastic still prevails among producers and consumers. Heidbreder et al. (2019) reviewed the perceptions of the public on the plastic problem and summarized that people value and use plastic, despite its potential harm to the environment.

2.1. Plastic packaging

Approximately 40% of the plastic demand is on packaging and 61% of the total post-consumer collected plastic waste results from packaging (PlasticsEurope, 2019). Therefore, it is crucial to understand consumers' perceptions of packaging materials, and how it influences their purchase choices. Previous research shows that the materials of the packaging are not considered to be important when consumers select products (Gelici-Zeko et al., 2013). Instead, price and brand are believed to be far more important (Koutsimanis et al., 2012).

The improper use and disposal of plastic packaging and bags is increasingly considered by consumers to be an environmental problem (Fernqvist et al., 2015; Hartley et al., 2018; Lotze et al., 2018). The plastic packaging of food is a major contributor to plastic waste, and this has also received much media attention in recent years (White and Lockyer, 2020). Nevertheless, there are also studies that indicate how consumers consider plastic packaging and plastic bags to be convenient and functional, such as the way they help to protect products (e.g. meat, fruits) and keep them hygienic (Aday and Yener, 2014; Phillips, 2016). Plastic packaging on fruit and vegetables helps to extend the shelf life of food products, and thus also helps to reduce food waste. Efforts to recycle packaging can help to reduce plastic waste (White and Lockyer, 2020).

The new Packaging Waste Directive (EU) 2018/852 (European Commission, 2018a) intends to stimulate eco-design in packaging, as a crucial step in achieving high quality in respect of plastic waste end-of-life management. An eco-design approach may provide an added social value to plastic products - including, but not only packaging - encouraging customers to adopt responsible behaviours. Communicating the environmental quality of packaging is not only a marketing strategy, but also an effective way of educating the consumer to make the right choice. In fact, both at the purchase phase and at the point of end-of-

Fig. 2. Variety of uses of plastic.
(Source: authors.)

life disposal, consumers play a key role in the life cycle of a product. Fostering a culture of circularity in manufacturers is intrinsically linked with buyer's choices. Moreover, the design measures adopted for recycling are only effective if the consumer makes the right decision at the purchase and disposal phases.

Because of the mandatory goal of plastic packaging being 100% recyclable by 2030, as stated in the "Strategy for Plastics in a Circular Economy" (European Commission, 2018b), the packaging industry and market have to adopt robust actions in the empowerment of consumers to encourage people's behaviour towards the utilization of compostable and biodegradable plastics (Foschi and Bonoli, 2019). However, this is already happening in some countries. Thanks to consumer pressure, for example, the fossil-based plastic carrier bags market has effectively reacted by transitioning to biodegradable and bio-compostable plastic carrier bags (http://www.assobioplastiche.org/). Biodegradable plastics represent a huge opportunity since they can be disposed and recycled as organic matter. However, their benefits can be effective only if combined with an accurate consumer awareness campaign.

2.2. Plastics in the aquatic environment

The detrimental impacts of plastic pollution are quite visible in the aquatic, especially in the marine environment (Leal Filho et al., 2019). So-called single-use plastics like plastic bags and straws are especially detrimental to marine fauna and flora (Schnurr et al., 2018). Despite this, many people are still uninformed about the legislation and regulations against disposing of plastic into the marine environment (Li et al., 2016). There are multiple examples of ongoing international legislative action to tackle the issue of plastic marine pollution, resulting from plastic bags and microbeads. This action has been supported by an increase in public awareness driven by international organisations (Schnurr et al., 2018).

2.3. Microplastics

Microplastics have received significant attention in media and research, but there is little information on people's perceptions of microplastics and their risks. This could be due to the size of microplastic particles -which cannot be seen by the naked eye- and the fact that it cannot be easily recovered from the environment (Heidbreder et al., 2019) and hence are not within the direct reach of most people. This could be one of the reasons why the environmental problems posed by microplastics are not considered by most people to be as serious, as those posed by larger plastic materials (Anderson et al., 2016). However, microplastics are known to pose significant negative effects on terrestrial and sea animals as well as to human health, be it directly or indirectly (Proshad et al., 2018; Wong et al., 2020).

2.4. Bioplastics

There is no standardised definition of what constitutes a bioplastic to date. Within the current, most widely accepted meaning, a bioplastic is a bio-based and/or biodegradable material (European Bioplastics 2019). Nevertheless, the European Commission aims to avoid the usage of the term 'bioplastics' and to focus further research and development on bio-based plastics, which can be biodegradable or not. However, internationally, there are three major categories of bioplastics:

- Biosourced (obtained from renewable resources) and biodegradable materials.
- Materials made using fossil fuels (oil) but made biodegradable.
- Biosourced or partly biosourced materials with the same structure as conventional plastic (non-biodegradable).

At present, bioplastics are an important part of the bioeconomy, which is worth 2 trillion euros in annual turnover and accounts for 22 million jobs in the EU (European Bioplastics, 2019b). Bioplastics can potentially make a considerable contribution to increased resource efficiency through a closed resource cycle and the use of cascades, especially if bio-based materials and products are either reused or recycled or used for energy recovery.

According to Smithers Pira's report "The Future of Bioplastics for Packaging to 2022" (Smithers Pira, 2017), global bioplastics consumption reached 1.06 million tons in 2017, with a market value of US$ 3.4 billion. At present, in the packaging market, bioplastics represent less than 1% of global plastic packaging sales. However, bioplastic packaging is forecast to grow at a significantly higher rate than petro-based polymers. Europe is the largest regional market for bioplastic packaging, and it is responsible for one third of the global consumption in 2017.

Public awareness of plastic seen as land and marine debris is growing, as a result of media coverage. In addition, marine conservation organisations have a crucial role in promoting and providing information on the cleaning of beaches and can subsequently help to raise public awareness (Thompson et al., 2009). The publicity in different media

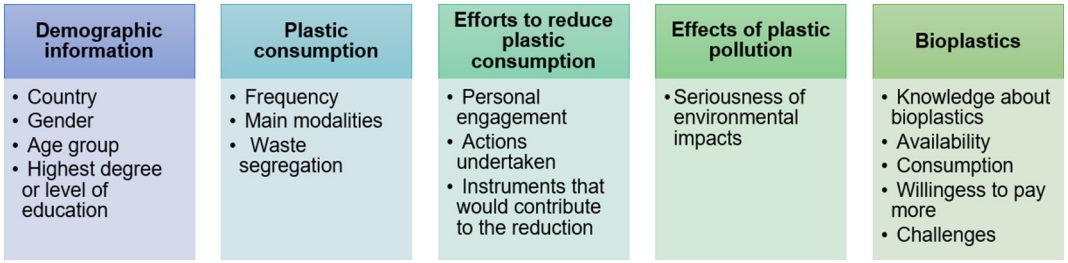

Fig. 3. Summary of each survey section and covered topics.

on the activities of NGOs has helped to raise public awareness when it comes to the gravity of plastic pollution and marine litter globally (Kershaw et al., 2011). With the participation of volunteers in beach cleaning campaigns, the organisers can also promote a sense of responsibility in protecting the terrestrial and marine environments (Kordella et al., 2013). There have also been successful programmes promoting public awareness and co-responsibility for marine litter in the European context. One such example is a project funded by the European Commission, completed in 2015 - MARLISCO (Marine Litter in Europe Seas: Social Awareness and CO-Responsibility), which included 15 countries and promoted the social engagement of several stakeholders (Veiga et al., 2016).

Now, as public awareness is increasing, it is important for environmental legislation to support the mitigation and control of plastic waste in the marine environment, so that, in the future the disposal of plastics in the sea, may be prevented (Bonanno and Orlando-Bonaca, 2018). In some European countries, the increasing public awareness has already contributed to new taxes on single-use plastics (McNicholas and Cotton, 2019).

The previous sections of this paper provided a background on the problems related to plastic production and use. The following European-wide study, presented in the next section, is based on the need for research on the attitudes of consumers about plastic production and use.

3. Methodology

As earlier stated, Europe is responsible for a considerable amount of the plastic being produced and consumed today. However, it is unclear if Europeans are aware of the impacts of their actions, as consumers of plastic products.

Therefore, departing from the research question, 'To what extent are Europeans using plastic products, and how aware are they of the current problems posed by plastic waste?', an online survey was prepared to assess the perception of Europeans on plastic waste as a whole and on bioplastics in particular.

In order to check the effectiveness of the approach used, the list of questions was prepared by the authors and pre-tested with partners of the BIO-PLASTICS EUROPE project (www.bioplasticseurope.eu). The final version ended up with 18 questions, divided into different sections as presented in Fig. 3.

The aim of this survey was not only to investigate details on plastic consumption, but also on the efforts to reduce it (Dilkes-Hoffman et al., 2019), the measures that could encourage this consumption to decrease (Heidbreder et al., 2019), and the efforts to curb plastic pollution (Hammami et al., 2017). Furthermore, the last section of the survey instrument tried to address some of the open questions related to the issue of bioplastics (European Bioplastics, 2019a; Van den Oever et al., 2017). It respondents about the characteristics of bioplastics, their availability in their countries, the factors that hinder the use of bioplastics, and their willingness to pay more for it.

The survey was disseminated to all partners of the Horizon 2020 project BIO-PLASTICS EUROPE. Additionally, the survey was also disseminated in European JISCMail mailing lists related to sustainability and sustainable consumption. The link remained active during February and March of 2020 and received 127 responses from 16 European countries. Fig. 4 presents a map with the countries represented in the study, and the scale of the number of responses.

According to Fig. 5, which shows the sample's demographic details, the respondents have rather balanced characteristics when it comes to gender and age group. When it came to the highest level of educational attainment, 50% of respondents (n = 63) indicated a Masters degree, 22% (n = 28) PhD or higher and 20% (n = 26) Bachelor's degree. The educational profile of rest of the sample (8%) was divided between Trade School and High School or less.

The data was analysed using descriptive statistics, with frequency tables, measures of central tendency and dispersion. To identify possible associations between the profile variables and the issues that refer to the influence on the frequency of use of plastics and bioplastics, engagement to reduce consumption, and a willingness to pay more for more sustainable options, a Chi-square test was used while considering nominal scale variables (categorical). In order to identify significant differences between the profile variables in relation to variables of environmental problems, which were measured on an ordinal scale (5-point Likert Scale), nonparametric tests were applied. The Mann-Whitney test was used for comparisons between gender categories, while the Kruskal-Wallis test was used for age and level of education. This was followed by the Mann-Whitney test with a Bonferroni correction, for variables where the Kruskal-Wallis test indicated significant differences between the groups.

The responses to 'How willing would you be to pay more in your everyday life in order to consume bioplastic products rather than regular plastic products' and 'How often do you use bioplastics in your everyday life?' were coded on a 5-point Likert Scale (e.g. Extremely and Always coded as 5; Not at all and Never coded as 1). For both variables, the analysis was equivalent to the one used for those measured on a 5-point Likert scale.[1] The statistical inference was performed considering a significance level of 5% and through the software SPSS v. 24.0.

4. Results and discussion

4.1. Trends on plastic consumption

As stated earlier, plastic is used all over the world. Of the 127 participants of the survey, the majority of respondents (63.8%, SD = 0.518) use plastic products on a daily basis. Of those respondents, plastic packaging (61%) was the most frequently used modality, followed by plastic bags (24%) (Fig. 6). In addition, 35% of participants use plastics occasionally while only 1.6% of participants use plastics rarely (the products used were namely longer-lasting items of everyday life like electronic gadgets having a plastic casing, etc.). This demonstrates that a majority of participants – irrespective of their age, country of origin or education – use plastic products daily. This corroborates with the study conducted

[1] For the frequency of use of bioplastics, the option "I do not know" was removed from the scale, due to the inability to provide an opinion.

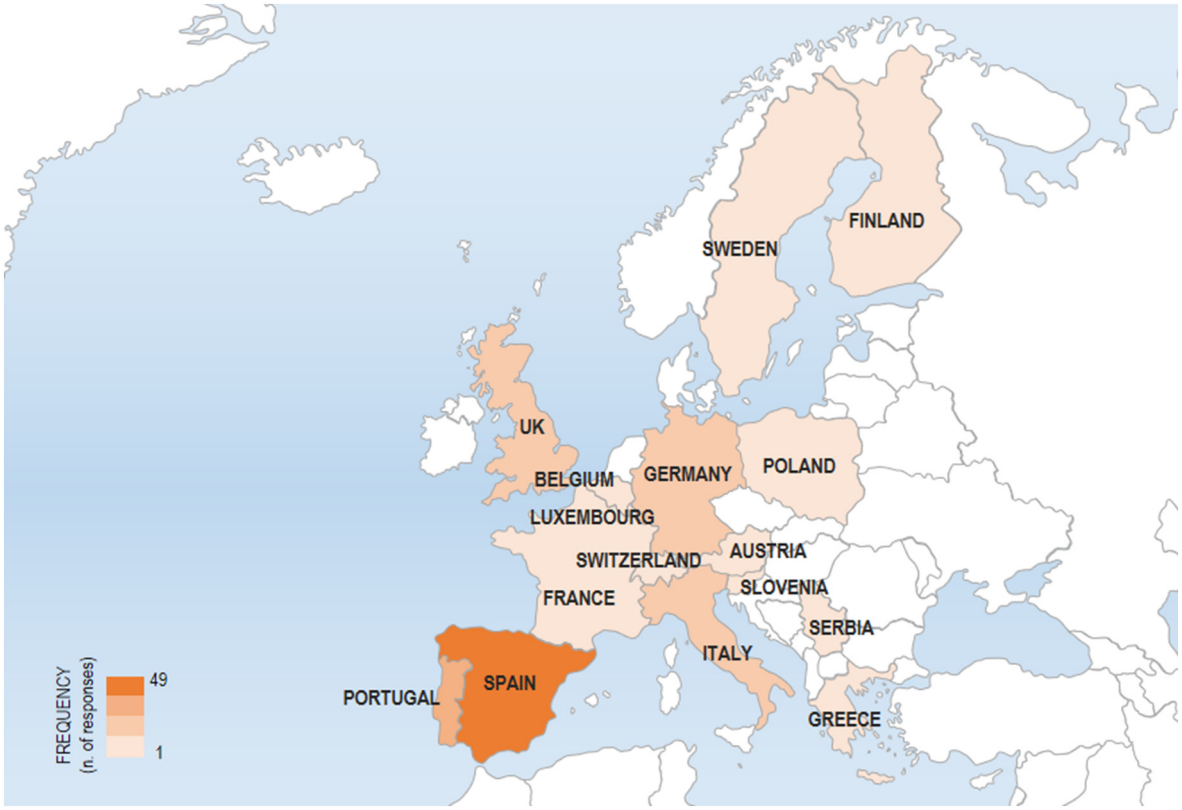

Fig. 4. Survey participating countries.

by Dilkes-Hoffman et al. (2019) in Australia, O'Brien and Thondhlana (2019) in South Africa, and Otsyina et al. (2018) in Kenya. The main attributable reason for this could be its plethoric presence, making it difficult for participants not to use it in everyday life.

Regarding plastic waste management, a large percentage of the respondents (74%) do segregate plastic waste and dispose of it properly in the specific containers as per their country's regulations. Alternatively, some respondents do not use segregation when handling plastic waste (Fig. 7). In order to encourage more people to segregate, Ergen et al. (2015) suggested raising awareness and tightening regulations. This could increase pro-environmental initiatives and could reduce the violation of set regulations.

4.2. Effects of plastic pollution

The understanding of the effects of plastic pollution on the environment by respondents was measured using a 5-point Likert scale. The bulk of participants across European countries perceived the issues of 'plastic in the ocean' and 'amount of plastic waste produced' as extremely serious (Fig. 8). Other serious issues were 'amount of plastic waste going to landfill', 'plastic waste polluting water' and 'endangerment of species and biodiversity'. In contrast, many respondents did not perceive soil pollution, air pollution (Liboiron, 2015), and effects on climate change (Zheng and Suh, 2019) by plastic waste as being extremely serious.

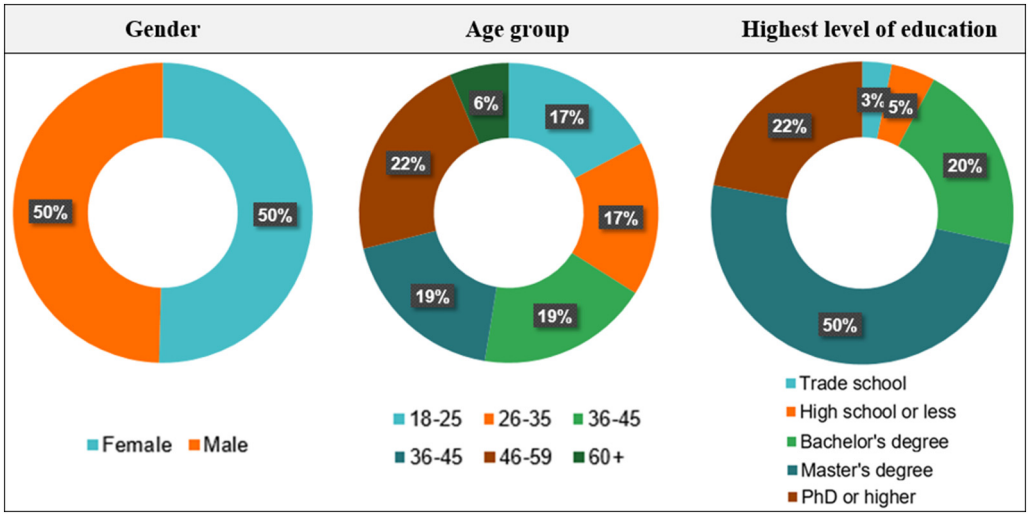

Fig. 5. Sample demographic details (gender, age group and highest level of education).

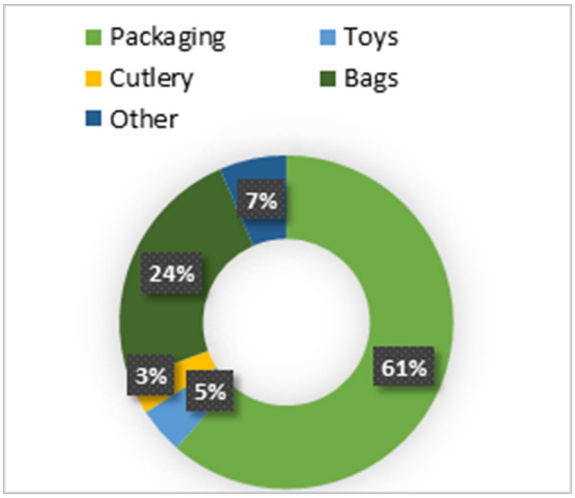

Fig. 6. Main modalities of plastic use.

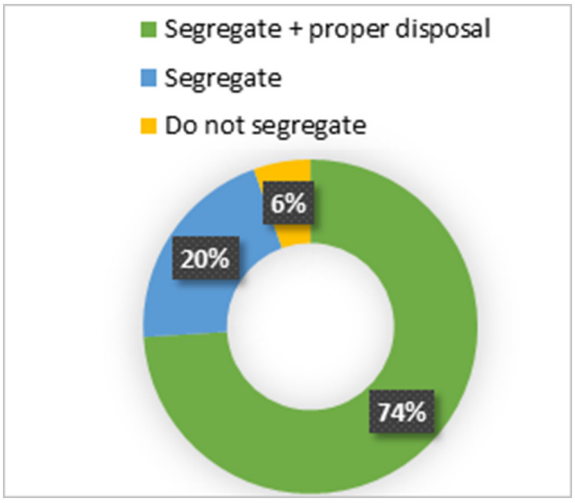

Fig. 7. Approaches to plastic waste management.

The data nonetheless indicate a growing concern among respondents about the negative effects of plastic on the environment, which is aligned with many other studies done in the past (Kershaw et al., 2011; Otsyina et al., 2018). However, the distribution of priorities has slightly changed recently, since issues like ocean pollution and plastic production have been more recently emphasised by the media and by research (Dilkes-Hoffman et al., 2019, Hammami et al., 2017). As a consequence, other serious issues are seldom brought to the surface.

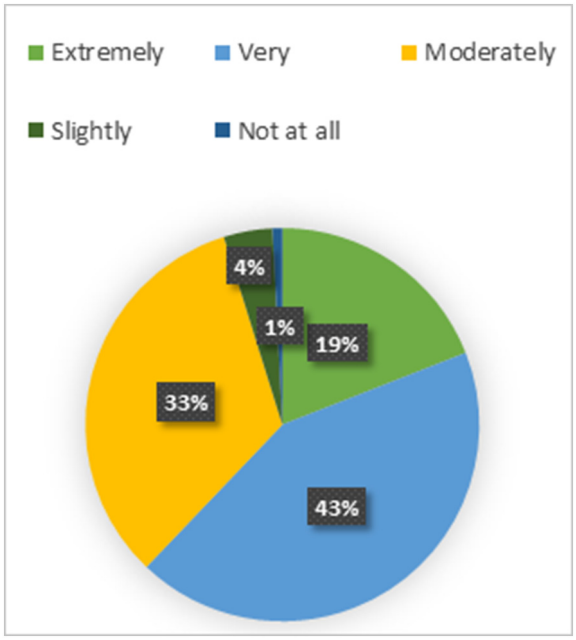

Fig. 9. Level of engagement in reducing plastic use.

4.3. Efforts to reduce plastic consumption

Most participants consider themselves to be 'moderately' to 'very' engaged in reducing plastic usage (Fig. 9). Various actions undertaken to curb plastic usage were categorised cumulatively as 1) 'No to plastic products' like bags, bottles, straws, plastic cutlery, and other single-use plastic items; 2) 'Minimizing the use of it' by choosing products with less plastic or packaging-free products; 3) 'Using sustainable alternative products' like using personal water bottles and cups, among others products (Fig. 10). This self-motivation among the participants to reduce plastic consumption suggests a shift in the paradigm from antagonist to agonist behaviour (Cecere et al., 2014).

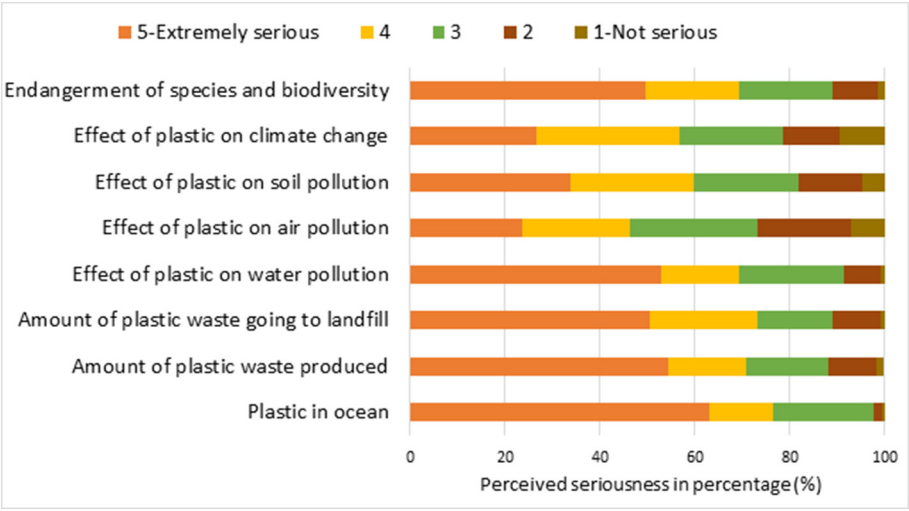

Fig. 8. Perceptions of environmental issues and problems associated with plastic.

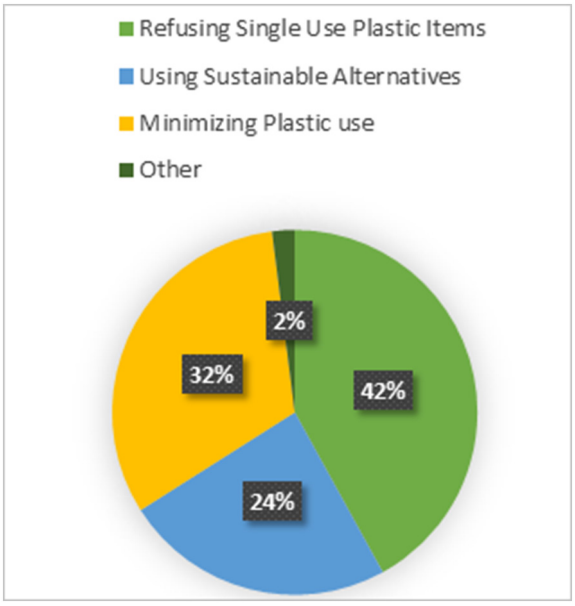

Fig. 10. Actions undertaken to reduce plastic use.

Factors like gender, educational background, and age seem to play a significant role in the level of engagement to reduce plastic usage and the actions undertaken. Statistical inferences indicate a significant association ($p < 0.05$) between gender, age, and the actions undertaken to reduce plastic use, and Chi-Square Tests were performed to confirm this association. As for gender, women were more active in reducing plastic use; a higher proportion of women refuse straws (χ^2 (1, N = 127) = 5.132, p = 0.018) and cutlery (χ^2 (1, N = 127) = 3.529, p = 0.045), choose products with less plastic (χ^2 (1, N = 127) = 6.138, p = 0.011) and bottle their own water (χ^2 (1, N = 127) = 9.917, p = 0.001) when compared to men. Fisher's Exact Test confirmed these associations. When it comes to age groups, respondents between the ages of 18–25 and 36–45 were among those choosing products with less plastic (χ^2 (4, N = 127) = 9.830, p = 0.043) and bringing their own takeaway cup (χ^2 (4, N = 127) = 10.359, p = 0.035). A Pearson Chi-Square test confirmed these associations.

Respondents were also questioned about which measures would assist them in reducing their plastic use. Measures related to raising awareness and educating people proved to be effective in a study done with young people (10–24 years as per the World Health Organisation) in the USA, which shows a positive correlation between environmental knowledge and pro-environmental attitudes and behaviour (Meinhold and Malkus, 2005). The opinion of the majority of the sample (73%) is aligned with the results obtained in the USA, similarly stating that educational and awareness-raising initiatives (e.g. educating school children, campaigns to raise awareness for plastic pollution, training of stakeholders, participation in plastic-reduction activities) would be a positive approach. Almost 75% of the sample also indicated the importance of regulatory instruments to reduce plastic use (i.e. full or partial bans on plastic bags or other plastic items). Furthermore, 55% participants also pointed out that economic policy instruments (i.e. fees, levies or taxes paid by the industry or consumers) could play a role in discouraging plastic use, and 56% and 63% of the respondents indicated that accessibility to recycling schemes and more infrastructure for recycling and reuse would be beneficial when it comes to avoiding plastic waste (i.e. beverage containers or plastic bags), respectively.

4.4. Bioplastics

The research instrument also paid a special attention to the subject matter of bioplastics. Based on knowledge gained via various resources in daily life about bioplastic, almost 38% and 35% of participants classified it correctly as 'biodegradable' and 'bio-based', respectively (European Bioplastic, 2020b). More than half (53%) of participants were aware of the properties of bio-based and biodegradable plastic materials. This can be considered rather low, taking into account that 92% of the respondents are people with a university degree. The contributing factor towards an increased level of awareness could be the occupational background of participants. Even then, the term 'bioplastic' did not seem to be clear to some participants; this was also evident in the previous studies of Blesin et al. (2017), Sijtsema et al. (2016) and Lynch et al. (2017).

The analysis indicated a significant association between the respondents' level of education and their awareness of the concept of bioplastics (χ^2 (1, N = 127) = 20.822, p = 0.001). Participants with an educational level of Ph.D. or higher (89%) were more aware of the difference between the terms 'bio-based' and 'biodegradable' in comparison to other groups. This finding is in line with previous research results on the impacts of the level of education and social status on the environmental awareness of people and their concern about the environment (e.g. Jones and Dunlap, 1992; Sonenshein et al., 2014). In addition, in the environmental education literature, those with a lower level of education have also been found to be less conscious of environmental problems (Liefländer et al., 2013).

The respondents were also keenly aware of the environmental issues posed by plastic and showed a positive inclination towards bioplastic use. A considerable percentage of respondents (38% and 29%) (M = 3.19, SD = 1.111) were 'moderately' or 'very' willing to pay extra in order to consume bioplastics (Fig. 11). In terms of the frequency of use of bioplastics (M = 2.60, SD = 0.815), less than 10% of the sample indicated the more frequent categories (Always 0.8% and Often 8.7%), and almost 30% of the sample chose the option 'I do not know', probably due to the fact that there is not enough available information on the topic.

In fact, 93% of the respondents indicated that information about bioplastics for consumers is insufficient, particularly in Portugal, Spain, and the UK. 85% of the sample mentioned that bioplastics are not easily available as a choice in their countries. Additionally, the results indicated no influence of gender, age or education level on the frequency of use of plastics or bioplastics, nor on the willingness to pay more for bioplastics.

The multidisciplinary factors impeding the routine use of bioplastics are summarized in Fig. 10. Many participants recognized a lack of or insufficient support from governments, as well as a higher price of bioplastic products, as obstacles. However, Van den Oever et al. (2017) mention that even though many suppliers would be ready to produce bio-based or biodegradable plastic, its production would still

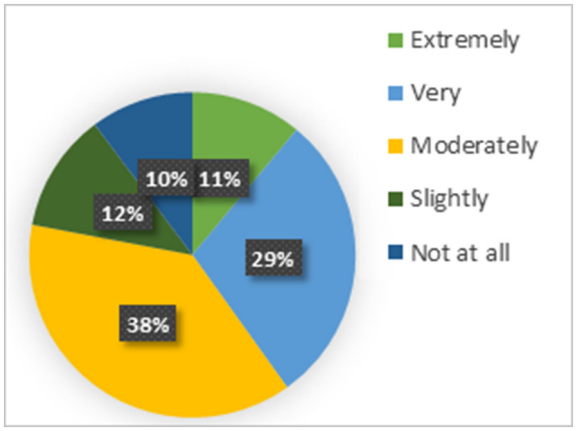

Fig. 11. Willingness to pay extra for bioplastics.

be rather low -it is currently around 1% of the overall plastic production - due the extremely low production costs associated with conventional plastic production. In addition, some participants mentioned other challenges when it comes to bioplastics usage, such as: 'potential to substitute fossil-based plastics', 'degree of biodegradability', 'impact of bioplastics on the environment', and 'ambiguity regarding composition' (Fig. 12).

Some participants reasoned with different arguments about why bioplastics would not solve the problem of plastic pollution. They call for behaviour change in industry and commerce as well as a general reduction in the consumption of plastic. Others are in favour of the introduction of higher taxes on conventional plastic materials. The suggestion of exchanging plastic for glass or metal also appeared as a comment, as indicated by participants in the study performed by Dilkes-Hoffman et al. (2019).

On the other hand, the respondents were very well aware of the environmental issues posed by conventional plastic materials, and also showed a positive inclination towards bioplastic use. The authors of this study recommend closing the gap of knowledge among citizens, in order to foster bioplastic usage. The introduction of labels like 'bio-based' and 'biodegradable plastic' on products, as suggested by Van den Oever et al. (2017), could help consumers when making their decisions.

When considering these results, it is obvious that bioplastics are a potentially sustainable solution to mitigate the effects of plastic waste on the environment. This hypothesis is supported by Van den Oever et al. (2017), as it may also lower non-renewable energy use (NREU) and greenhouse gas (GHG) emissions associated with the production of conventional plastic products. Most bioplastic materials may degrade completely under controlled conditions, therefore preventing a waste pile-up and providing overall food safety -in packaging of food products- when compared to regular plastic. However, much research is still needed, especially in the area of the production and end-of-life of bioplastics. There are still many unanswered questions, but despite this, many positive outcomes can be observed. Therefore, Fig. 13 might support governments when designing future policies to curb plastic usage.

4.5. Limitations of the study

There are two main limitations to this study. The first relates to the limited number of responses. The total of 127 responses from 16 European countries cannot be regarded as representative from a statistical point of view. However, it serves the purpose of building a rough profile of European trends. The second limitation relates to the scope of the study, which involved European universities and research institutes, a group which is presumably well informed and properly educated about this topic. The data and evidence gathered from the study are nonetheless robust, in the sense that it offers unprecedented insights into how representatives of education and research institutions perceive the use and disposal of plastics, along with their levels of information and attitudes about bioplastics. As far as the latter aspect is concerned, less than 10% of the respondents stated they use bioplastics. This is a trend that may be addressed through the provision of more information on alternatives to conventional plastic available today.

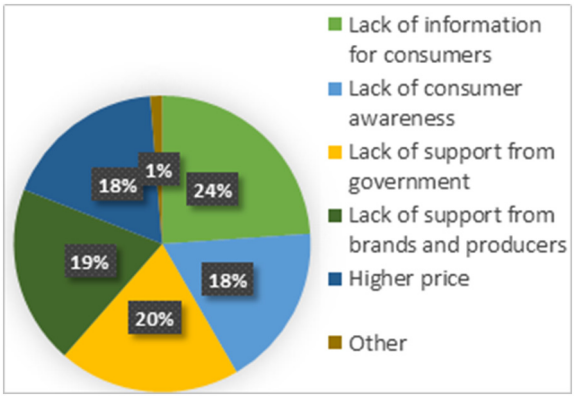

Fig. 12. Challenges in the use of bioplastics.

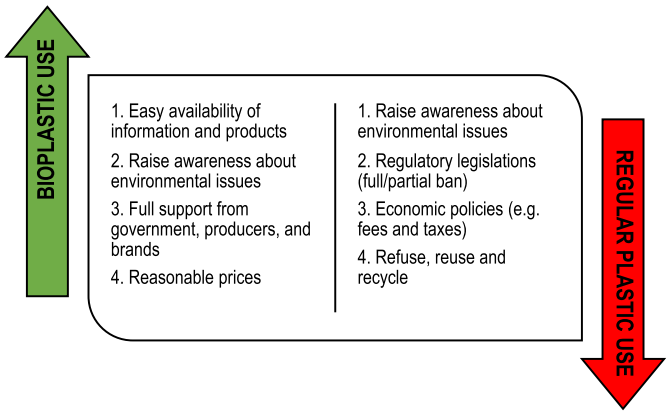

Fig. 13. Illustration of the survey's conclusions to promote bio-based and biodegradable plastic and abate regular plastic use.

5. Conclusions

This article evaluated the attitudes and perceptions of Europeans on the use of plastics and bioplastics, associating them with their profile and characteristics. Evidences gathered from the study suggest that the majority of those surveyed showed a) an awareness about the problem and b) an interest to be engaged in reducing the use of plastics and adopting sustainable alternatives.

The survey also shows that the participants have a good knowledge of bioplastics, whereby more than half had knowledge about the material properties of bio-based plastic materials. This feature stands out in participants with a higher educational level, who demonstrated the awareness of the difference between the terms 'bio-based' and 'biodegradable' when compared to other groups.

The data also demonstrate an overall degree of concern among respondents about the amounts of plastics produced and the potential or likely impacts of plastic contamination in terrestrial and aquatic environments. These problems suggest the need for information campaigns that warn about the damages caused by the consumption of plastic products. However, this may not be enough, as indicated in a study conducted by Latinopoulos et al. (2018), where they found that local residents may be willing to financially support the protection of their coastal and marine environment to preserve landscape quality and fisheries, but information campaigns do not have a major impact on the way people perceive the risk of plastic waste on the natural environment. This means that the enforcement of the extended producer responsibility driven by policies among companies producing plastics is especially important in preventing the potential damages to the natural environment (Leal Filho et al., 2019).

The participants considered issues related to water pollution by plastic materials as very serious. The attention directed to water pollution may be due to the widespread dissemination of this topic by the media. In contrast, the issues that refer to air and soil contamination are also extremely relevant but have a less expressive dissemination.

The implications of this research are two-fold. First, it is expected that the present findings may offer an effective and interesting picture of European citizens' behaviour and attitudes in relation plastics utilization. Secondly, it shows that apart from policy decisions, greater efforts are needed towards raising more awareness on the impacts of fossil fuel-based plastics use and on the search for more sustainable

alternatives, especially in respect to reduce current use of plastics and to create more sustainable materials such bioplastics. The combination of sound policies and improved awareness, may help to address the problem and, inter alia, may help to alleviate the pressures currently imposed to the physical environment.

CRediT authorship contribution statement

Walter Leal Filho: Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Amanda Lange Salvia:** Data curation, Formal analysis, Methodology. **Alessandra Bonoli:** Investigation, Writing - original draft, Writing - review & editing. **Ulla A. Saari:** Investigation, Writing - original draft, Writing - review & editing. **Viktoria Voronova:** Investigation, Writing - original draft, Writing - review & editing. **Marija Klõga:** Investigation, Writing - original draft, Writing - review & editing. **Sonali Suraj Kumbhar:** Data curation, Formal analysis, Methodology. **Katharina Olszewski:** Data curation, Formal analysis, Methodology. **Daniela Müller De Quevedo:** Data curation, Formal analysis, Methodology, Software. **Jelena Barbir:** Conceptualization, Funding acquisition, Investigation, Project administration, Validation, Visualization, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study 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.

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