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Exploring perceptions of environmental professionals, plastic processors, students and consumers of bio-based plastics: Informing the development of the sector

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ABSTRACT

Bio-based plastics are produced from bio-based raw materials such as sugar cane, potatoes, corn, and agricultural and slaughterhouse waste. The evolution of the bio-based plastics market is affected by the stakeholders involved owing to their role in production processes, environmental guidelines and purchasing decisions. It is therefore imperative to understand the perceptions of stakeholders in order to inform the development of the bio-based plastics sector. This novel exploratory study investigates the perceptions and opinions of three stakeholder groups: environmental professionals and plastic processors; university students; and consumers in Belfast, Northern Ireland. During the focus groups (25 participants in total), samples of bio-based plastics, including starch-based monolayer and multilayer, and polyethylene terephthalate (PET), were presented. A qualitative analysis using the framework method revealed that environmental professionals and plastic processors were aware of both the benefits of bio-based plastics, such as a reduction in use of fossil fuels; and the challenges, which include the utilisation of agricultural land for biomass substrates and possible contamination of current conventional plastic recycling streams. Although there was a general lack of knowledge among students and consumers about bio-based plastics, they conveyed their beliefs that the use of agricultural waste will lead to closed-loop systems, resulting in a balanced approach to production and waste management. Some students and consumers, raised concerns about contamination of food by bio-based packaging prepared from slaughterhouse waste. However, these participants supported the use of slaughterhouse waste in the production of bio-based plastics for non-food contact items. The students and consumers and some of the environmental professionals and plastic processors were reluctant to pay more for bio-based plastics. The results indicate that manufacturers of bio-based plastics could benefit from informing consumers about the environmental impacts of beginning-of-life parameters, such as production processes and feedstocks, by using life cycle assessment parameters. This should be incorporated into information provided on labelling using standards from neutral organisations. This research could inform future communication strategies around bio-based plastics with both the public and industry.

1. Introduction

"Clean growth is not an option, but a duty we owe to the next generation, and economic growth has to go hand-in-hand with greater protection for our forests and beaches, clean air and places of outstanding natural beauty" (The Clean Growth Strategy, UK, 2017). A thriving innovation-based bioeconomy, which exploits renewable biological resources and converts waste streams into value added products for industry, forms an integral part of the Clean Growth Strategy.

A potential building block of the bioeconomy could be plastic based on renewable resources, as developing innovative bio-based products promotes sustainability at an early stage (European Commission 2012). Plastics have found their use in a variety of applications in today's society, with annual global production reaching 359 million tonnes by 2018 (PlasticsEurope 2019). The ma-

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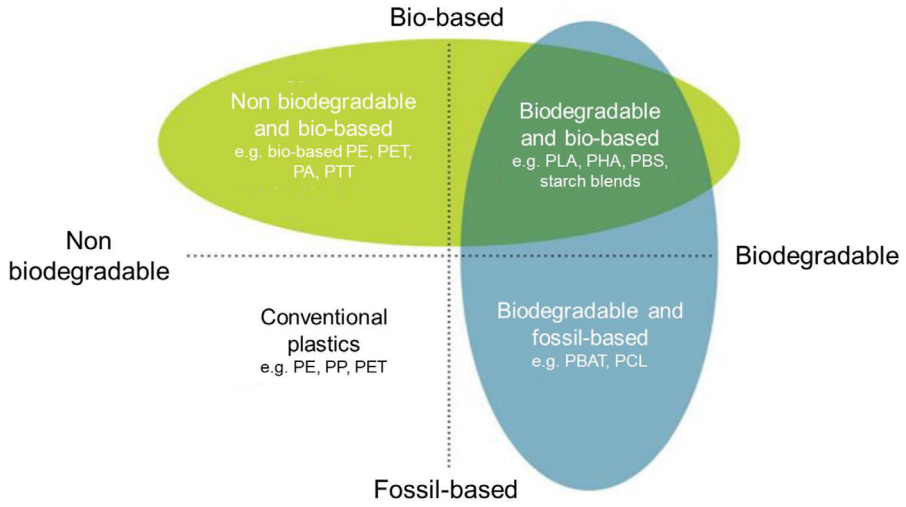


Fig. 1. Definition of bioplastics (adapted from European Bioplastics (n.d.)). The present research focuses on bio-based plastics produced from renewable sources. PE: polyethylene, PET: polyethylene terephthalate, PA: polyamide, PTT: Polytrimethylene terephthalate, PLA: Polylactic acid, PHA: Polyhydroxyalkanoates, PBS: Polybutylene succinate, PBAT: Polybutylene adipate terephthalate, PCL: Polycaprolactone, PP: Polypropylene.

jority of plastics are based on fossil fuels, but against the background of depleting resources, increasing CO_2 emissions and climate change, bio-based plastics could provide suitable alternatives (Confente et al., 2019; Dilkes-Hoffman et al., 2019a).

Bio-based plastics are produced from renewable raw materials and can be either biodegradable or non-biodegradable (Álvarez-Chávez et al. 2012; Dietrich et al., 2017; Endres and Siebert-Raths, 2011) (**Fig. 1**). They can be produced from raw materials such as sugar cane, potato or corn starch, cellulose, various plant oils, corn husk fibres, soy protein, and food and animal waste like fish waste, algae and poultry waste (Álvarez-Castillo et al., 2019; Jiménez-Rosado et al., 2020; Saenghirunwattana et al., 2014; Sadhukhan, 2017; The James Dyson Award, 2019). The use of renewable raw materials can have a positive impact on the environment depending on the cultivation methods (Hottle et al., 2013; Piemonte and Gironi, 2011), and can contribute to a reduction in CO_2 emissions and lower climate change effects (Hermann et al., 2007; Khoo, 2019; Mehmood et al., 2017; Pawelzik et al., 2013; Scherer et al., 2018).

Although the market is currently dominated by fossil-based feedstock, bio-based plastics are slowly gaining a market share, with the major use being in consumer packaging applications (BBIA 2019, European bioplastics 2017). In 2018, around 7.5 million tonnes of bio-based plastics were produced globally forming about 2% of global plastic production (Nova-Institute 2019). However, the development and application of policies surrounding their functional range, and the evolution of the bio-based plastic market, are widely affected by stakeholders involved in bio-based products. Because an evolving shift or transition from fossil-based plastics to bio-based plastics must be technologically feasible, economically viable and socially desirable (Ingram and Endter-Wada, 2009; Taufik et al., 2020), it is important to gain insights into stakeholder perceptions. Therefore, the aim of this research is to inform the development of the sector by exploring stakeholder opinions and perceptions towards bio-based plastics.

Previous studies have explored consumers' perspectives of various bio-based products using opinion surveys (Carus et al., 2014; Klein et al., 2019; Klein et al., 2020; Onwezen et al., 2017; Reinders et al., 2017; Scherer et al., 2017; Wurster and Schulze 2020). Other research involving website analysis, along with interviews and focus groups with environmental and plastics professionals and policymakers, investigated communication about and perception of bioplastics, and presented findings on perspectives, interests, strategies and measures that have influenced public communication on bioplastics (Blesin and Möhring, 2020). Building on previous research, this current study seeks to support the development of the bio-based plastics sector through using a broader scope to explore the perceptions of a range of stakeholders. The importance of such research in developing the bio-based plastics sector, and the bioeconomy as a whole, has been highlighted by Dilkes-Hoffman et al. (2019a) and Mukhtarov et al. (2017), but to the authors' knowledge there are no such studies in the literature. This paper seeks to address this knowledge gap.

There is much to be gleaned on consumers' perceptions towards bio-based plastics and products from previous work in the literature. Scherer et al. (2018), when identifying the factors affecting consumer choices, concluded that respondents with a preference for organic food showed more inclination towards sports equipment from bio-based plastics. What is also interesting is that Klein et al. (2019) identified that socio-demographic factors have no influence over the purchasing decisions of bio-based plastics. Klein et al. (2020) identified that green consumer values and attitudes influence preferences towards the attributes of bio-based products such as the origin of resource of feedstock and the percentage of bio-based material in rain jackets. Onwezen et al. (2017) found subjective ambivalence existed in relation to bio-based plastic purchasing intentions among consumers from six European countries (Czech Republic, Denmark, Germany, Italy, Slovenia and The Netherlands). Conversely, Reinders et al. (2017) in two experimental analyses in the same six European countries, identified that global brands with 100% bio-based features were rated high in acceptance by consumers compared to those that had partially bio-based features. This supports the findings of a survey of representatives from various plastic manufacturers and traders, which showed that 72% of the business owners believed that their consumers would pay 10-20% of the price as a green premium on their products (Carus et al., 2014). Other recent studies included opinion surveys which concluded that perceived consumption value (including economic and practical value) of green products influences consumers' willingness-to-purchase green or sustainable packaging (such as in China by Hao et al. (2019); in India by Singh and Pandey (2018); in Portugal by Martinho et al. (2015). Equally, lack of perceived consumption value may thwart purchasing of green or sustain-

able products (for example in South Africa by Scott and Vigar-Ellis (2014)). Russo et al. (2019) were able to conclude that green self-identity, age and past purchases impact upon the reactions and perceptions towards biodegradable plastics. Drawing on other recent studies, Lynch et al. (2017) conducted focus groups for analysing Dutch citizens' perspectives towards bio-refineries, biofuels and bioplastics, to explore perceptions of the transition to a bio-based economy, while Zwicker et al. (2020) applied an attitude network approach for studying consumer attitudes towards bio-based plastics, with the aim of understanding what encourages consumers to make more sustainable purchasing decisions. Wurster and Schulze (2020) recommended use of labelling with information on the sustainability of bio-based tyres in the automotive sector, to increase consumer knowledge on the topic.

Although a wealth of consumer studies is available in the literature, previous research has tended to focus on bio-based plastics in general and/or on crop-based feedstocks. Only two studies have been identified by the authors in which perceptions towards waste-derived bio-based plastics were investigated. Herbes et al. (2018) explored consumer attitudes towards different options for environmentally friendly packaging, with a focus on understanding the potential market for biomethane-based packaging. Attitudes towards biodegradable PHA (polymer-polyhydroxyalkanoates) were studied by Russo et al. (2019), but only in the context of food waste as a feedstock. Driven by circular economy principles, research into the development of bio-based plastics from various agricultural wastes is ongoing, including, for example, from slaughterhouse and crop wastes (Bolaji et al., 2020; McGauran et al., 2016). The circular bioeconomy in this context refers to the sustainable, resource-efficient valorisation of biomass in integrated, multi-output production chains while also making use of residues and wastes and optimising the value of biomass over time via cascading (Stegmann et al., 2020). However, at the same time it brings new questions about acceptability to the forefront. Given the lack of current research on perceptions towards waste-derived bio-based plastics and that design changes are considerably less expensive in the earlier stages of product development (Folkestad and Johnson, 2001), it is important to engage with stakeholders even during the research and development phase. This paper will qualitatively explore opinions and perceptions towards a range of feedstocks and, for the first time in literature, perceptions towards bio-based plastics from slaughterhouse wastes.

In summary, two main issues were identified from the review of the literature: (1) For the development of a bio-based industry, it is important to encompass the views of a range of stakeholders, but previous research has tended to focus on one group per study, e.g. consumers or professionals. (2) Existing research on perceptions towards waste-based bio-based plastics is limited and to the authors' knowledge there have been no studies on perceptions towards bio-based plastics made from slaughterhouse waste. Therefore, the objectives of this study are to: (1) Explore the perceptions of a range of stakeholders regarding bio-based plastics, (2) Investigate perceptions towards a variety of feedstocks, including slaughterhouse waste, a new feedstock for which perceptions have not been previously studied, and (3) Arising from the findings, make recommendations for supporting the development of the bio-based plastics sector.

2. Methods

2.1. Method of enquiry

In order to gain an in-depth understanding of stakeholders' perceptions of bio-based plastics we employed a qualitative method of enquiry, drawing on a constructivist paradigm. Within this paradigm, researchers are concerned with the subjective understanding of the world and social phenomena as well as the way in which the sociocultural environment interacts with and shapes an individual's existing knowledge and experience of a topic/concept (Bryman, 2016). This is particularly relevant to the current research aims as it enabled the researchers to explore terminology around bio-based plastics during interactions with samples and examine subjective perceptions in the sociocultural context of Northern Ireland (the region is subject to the Waste Framework Directive (European Commission 2008) and as such has a similar waste landscape to other countries in the European Union).

Focus groups were used for collection of data for our study. Focus groups are a common method of qualitative data collection and are well suited to the exploration of complex perspectives and the underlying reasons for individuals' decision-making within the context of the wider sociocultural environment (Bickerstaff et al., 2006). Typically, focus groups have sample sizes of around 6-10 participants per homogenous group, and samples may be selected to provide a variation of factors such as age and gender (Morgan and Krueger, 1998; Moser and Korstjens, 2018). The homogeneity of each focus group enables researchers to explore a particular topic from the perspectives of participants who share certain broad characteristic(s) relevant to the research topic and aims (Ahmed et al., 2019; Anderson et al., 2016; Steckowych et al., 2019; Vaz-Fernandes and Caeiro, 2019).

2.2. Sample

Convenience sampling took place to recruit individual participants in Northern Ireland for the study between August and October 2019. Researchers posted an announcement about the study on Twitter; distributed leaflets; sent out emails to speakers who presented their work at the launch of UKRI-funded ACCEPT Transitions project (which deals with circularity in the plastics economy); distributed flyers in various Schools of the University; and invited the respondents of an online questionnaire to participate (who indicated an interest in taking part in the focus groups). A range of stakeholders were targeted, as previous research has recommended that the development of key initiatives in the bioeconomy should be supported by deeper exploration of the intersection of technological advancements, political regulations and consumer expectations; focus groups should therefore comprise not only consumers, but also industry, government organisations, charities, non-governmental organisations, waste handlers, universities, and plastic processors (Dilkes-Hoffman et al., 2019a; Mukhtarov et al., 2017).

Three stakeholder groups were explored for the present study (see group characteristics in **Table 1**): (1) Environmental professionals and plastic processors with expertise in technological advancements, policy and regulations. (2) Consumers who buy the products and thus make purchase decisions. Involving consumers as stakeholders leads to increased acceptance of emerging technologies and development of need-oriented innovation processes (Chilvers, 2008; Delgado et al., 2011). (3) Undergraduate, masters and PhD students of various academic disciplines: Young students and scientists of the future are now becoming more interested and active in environmental conservation making it important to obtain their perspectives and explore their understanding (Karasmanaki and Tsantopoulos, 2019).

The participants in all three groups were not known to the moderator before their participation in the focus groups. The environmental professionals and plastic processers (group 1) were recruited from a mixture of academia, local government, non-governmental organisations, charities, research organisations and plastics processing (**Table 1**) and had expertise in the areas of waste management, the plastics industry, biomaterials, public engagement and environmental issues. The plastic processors were

Table 1
Demographics of the participants (n=25)

FG1-FG2[a]	Area of work Environmental professionals and plastic processors	Age	Sex
1	Plastic manufacturing staff	45-55	M
2	Plastic manufacturing staff	45-55	M
3	Waste management staff	55-65	M
4	Scientific officer	35-45	M
5	Senior scientific officer	45-55	M
6	Plastics use and disposal officer	35-45	F
7	Postdoctoral researcher, QUB[b]	35-45	F
8	Waste management staff	45-55	F
9	Waste management staff	45-55	M
FG3	**Students (QUB)**		
1	Master's, School of Mechanical and Aerospace Engineering	18-25	M
2	Master's, School of Mechanical and Aerospace Engineering	25-35	M
3	PhD, School of Natural and Built Environment	25-35	F
4	PhD, School of Mechanical and Aerospace Engineering	25-35	F
5	PhD, School of Pharmacy	25-35	F
6	PhD, School of Mechanical and Aerospace Engineering	25-35	M
7	Undergraduate, School of Pharmacy	18-25	F
8	Undergraduate, School of Mechanical and Aerospace Engineering	18-25	M
FG4	**Consumers**		
1	Staff, QUB	25-35	F
2	Staff, QUB	35-45	F
3	Semi-retired	65+	M
4	Manager	55-60	F
5	Education management staff	25-35	F
6	Retired	65+	F
7	Retired	65+	F
8	Staff, grocery shop	25-35	F

Focus groups 1 and 2 included participants from a city council, governmental environment body, environmental charity, non-governmental waste and resources organisation, plastics processing facility, government agricultural and environmental research and development, and faculty of medicine, health and life sciences.
[a] *FG: focus group*
[b] *QUB – Queen's University Belfast.*

invited from a plastic processing facility in Northern Ireland, which is a commercial entity that provides applied research and solutions to plastic manufacturing businesses, works closely with industrial partners and represents perspectives of plastic manufacturers. When conducting research of this nature, bringing processors from competing businesses together is a challenge and so we needed to combine people from a number of backgrounds. However, the group that came together were not a disparate group, instead they held similar interests and concerns about the plastics industry. The students (group 2) had a range of background knowledge, including, in some cases, renewable energy, life cycle assessment, and contamination due to plastic waste (**Table 1**). No exclusion criteria were applied to focus group participants in the student group or environmental professionals and plastic processors group, which meant that, although participants were heterogeneous in terms of their academic or professional specialism, they shared the broad characteristic of being students (group 2) and environmental and plastics experts (group 1). No participants in the consumer group (group 3) were working in the petrochemical and energy sector, cosmetic industry, farming or market research. They also did not have expertise in the production of bio-based plastics. This group therefore shared the broad characteristic of being non-expert consumers.

The recruitment of the participants for the study ended when we had reached a sample size of around 7-10 participants per group. Along with the audio recordings, notes were taken during each focus group session. In line with Moser and Korstjens (2018), these notes were analysed after each session. From this, we observed consistency, patterns, categories, and variety in the key messages from all the groups and were therefore able to ascertain that a substantial and broad range of data had been collected, and hence that additional focus groups were not required.

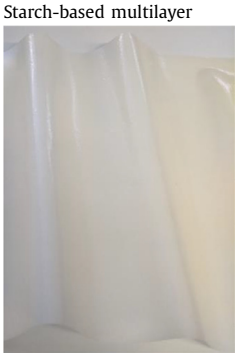
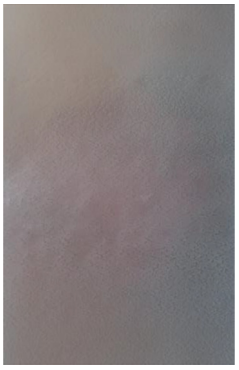
2.3. Process and analysis

The study was approved by the ethics committee of the Faculty of Engineering and Physical Sciences of Queen's University Belfast (**Ref. no. EPS 19-209**). The participants were invited to coffee and tea before the session and for lunch during/after the session to maintain an informal atmosphere. Participants were asked their dietary preferences (e.g. vegan, vegetarian, none) in the invitation. The reimbursement of travel costs was possible, on the request of the participant. No other monetary compensation was provided. The focus group discussions were of a semi-structured nature and were conducted according to a predetermined protocol. A **topic schedule (Supplementary material: S1)** was created with the list of questions to guide the focus group discussions.

At the start of the focus group, a cover page helped the participants to understand the definitions of and feedstocks for bio-based plastics and an information sheet provided the participants with insight into the focus group process (**Supplementary material: S2 and S3**). The moderator stressed that participants could stop the focus group and leave at any time and their data would then be removed from the final transcript. It was explained that names would be changed in the transcript and that no data would be traceable. Participants were reassured that the recorded discussions would be immediately transferred to a secure password protected computer file at QUB. The discussion was recorded digitally. The moderator used a standardised topic guide and questions to cover four main phases in the discussion, comprising: (1) Wider context, (2) Information gathering, (3) Reactions and (4) Ideas for change and the future outlook. Each participant read and signed a consent form (**Supplementary material: S4**).

During **step 1,** the participants were taken through an introductory icebreaker exercise. If participants had mentioned being vegan or vegetarian when responding to the focus group invita-

Table 2
The three plastic products used in focus group discussions

	Polyethylene terephthalate	Starch-based monolayer	Starch-based multilayer
Product			
			
Transparency			
Common uses	Bottles, packaging, synthetic fibres	Packaging	Packaging, cutlery
Characteristics	Fossil-fuel based plastic, conventional and widely produced	Cheap, abundant and renewable and one of the most commonly used bio-based plastics (Avérous and Pollet, 2014).	

The samples of products were obtained from the Plastic Processing Research Centre and the pictures of products and transparency were taken by the author using a phone camera.

tion email, then they could explain the reasons behind those preferences during this step. Participants also reflected upon uses of plastics in day-to-day life, such as shopping, and recycling of rubbish and plastics in households (summarised responses in **Supplementary material: S5** and quotations in **Supplementary material: S6**).

At **step 2,** participants read the cover page of the study again ensuring that all the participants understood the terminology around bio-based plastics before the discussion started. The participants were then prompted to think about bio-based plastics that can be prepared from biomass sourced from slaughterhouse waste, other agricultural waste, crops etc., and at this stage, the participants were asked what they thought of bio-based plastics. We were keen to understand how perceptions and feelings towards the source of bio-based plastics influence decision-making, particularly with regard to bio-based plastics with slaughterhouse waste as feedstock for various products.

In **step 3**, bio-based products (**Table 2**) were shown to the participants, who were asked if they were familiar with them and, if so, how they felt the products differed from conventional fossil-fuel based plastics. Both conventional polyethylene terephthalate (PET) and starch-based bio-based plastics were presented to the participants, as both of these variants of plastics are widely used in consumer products such as packaging and cutlery. Participants examined the products and passed them around the group. At this stage we were keen to explore the impact of witnessing and touching actual products. This is because physically holding products is important in product evaluation to identify users' perceptions of product appearance, functionality or usability (Christel et al., 2018). Physically holding products can cause variation in attitudes towards products due to increased sense of psychological ownership (William and Ackerman, 2011).

Finally, at **step 4** the moderator asked the group about their ideas on how bio-based plastics can lead to more sustainable paths. At the end of each focus group, participants had the opportunity to make final comments.

For management and summarisation of the responses, the framework method was used (Ritchie and Spencer, 1994). This content analysis method was chosen because of the pragmatic approach that helps manage large qualitative datasets and provides ease of collaboration across a multidisciplinary team (Parkinson et al., 2016). The analysis consisted of following steps: (1) Familiarisation with the data: The researchers (AC, NM) were involved in listening to the interviews and transcribing the audio files. The data in the transcripts was transferred to a password secured file folder. The data from the notes taken during the focus group discussions and the transcripts was read in the project update meetings (BS, EC, NM). (2) Identifying a framework, indexing and charting: The notes generated during the focus groups helped with the identification of initial themes. Following that, a table was created showing questions in a topic guide with columns for each individual group (i.e. environmental professionals and plastic processors, university students, and consumers) (**Supplementary material: S6**). Responses to each question were logged into the corresponding boxes until all the data in the transcripts had been transferred. (3) Interpretation: The research team (BS, EC, NM) then met to discuss the findings across the focus groups in response to each question to develop initial themes. Later on in the process, themes

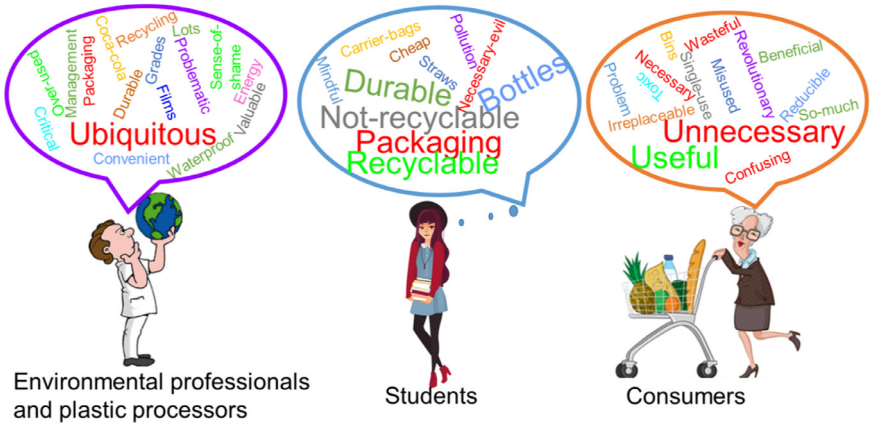


Fig. 2. Word cloud representing participants' views on plastics. The font size is proportional to the frequency with which a particular word was mentioned in the discussion. The font colour is random and bears no meaning. The extracted quotations from the focus group discussions are presented in **Supplementary material: S6**.

that appeared to convey similar meanings were grouped. No software was used for conducting the analysis; however, the word count was cross-checked with the Online Word Cloud platform – WordItOut (n.d.).

3. Results

Three key themes emerged as a result of the data from the focus groups: 'knowledge and concerns about bio-based plastics', 'willingness-to-pay for bio-based plastics', and 'opinions on the integration of bio-based plastics'. This section contains examples of the responses on plastic perceptions among participants and to each of the questions within these themes. For describing the participants in the study, quotation identifiers are inserted for environmental professionals and plastic processors (E), university students (S), and consumers (C) along with the number of participants with similar views.

3.1. Background knowledge and perceptions of plastics among participants

To elicit existing views on plastics, participants were initially asked to give a couple of words of what comes to mind when thinking about plastics. These words were extracted from the transcripts and were counted (cross-checked with the Online Word Cloud platform – WordItOut, n.d.). The environmental professionals and plastic processors thought about plastics in terms of different grades and energy recovery, and reflected that plastics are ubiquitous/everywhere.

My first thought would be 'ubiquitous'. When you go to the supermarket, nearly everything is covered in plastic – plastic films. (E #1)

The students viewed plastics principally as packaging, bottles, durable, recyclable and not so easily recyclable, and one commented that plastics are a necessary-evil.

Necessary evil – should be mindful of using. (S #1)

It was noted that both the environmental professionals and plastic processors and students focused on plastic products and words such as films, packaging, bottles, carrier-bags, durable, recyclable, not-recyclable, energy source, Coca-Cola™, grades and straws. On the other hand, the consumer reactions carried more adjectives or feelings and emotions. The consumers showed opposing views about plastics and perceived them as both unnecessary and also useful (**Fig. 2**).

Toxic would be something but also useful. (C #1)

The trend of the percentage of words with negative associations within various groups was observed as: Consumers (problem, toxic, unnecessary, wasteful, misused, reducible, so much) > Environmental professionals and plastic processors (Over-used, problematic, sense-of-shame, lots, ubiquitous and/or everywhere) > Students (Pollution, necessary evil, not recyclable).

3.2. Theme 1: Knowledge and concerns about bio-based plastics

In each focus group we encouraged the participants to reflect on the cover page of the study again, to gain understanding of the definitions and the various feedstocks used for bio-based plastics. After this we asked questions about their thoughts on replacing fossil-based plastic products with agriculturally-derived materials. We recorded that the environmental professionals and plastic processors were familiar with production of bio-based plastics; they mentioned that it will save fossil fuels in the long term. However, some of the environmental professionals and plastic processors spontaneously compared bio-based plastics to other environmental issues, such as production of fuels from biomass and the associated issues of food security and agricultural land management (additional extracted quotations can be found in **Supplementary material: S6**). Concerns were also raised about the recyclability of bio-based plastics. Environmental professionals and plastic processors also mentioned that bio-based plastics can replace a certain percentage of fossil fuel-based plastics in the current market share.

I think it's interesting to see fossil fuels replaced in some way, as they are running out. (E #3)

Do you take land away from food production and put that towards fuel/plastic production? Can cause problems with food supply and price. (E #3)

We do not need any more complications and complexity for recycling streams. (E #2)

The students and consumers at this stage asked questions (summarised in **Table 3**). They also enquired about the difference between bio-based and biodegradable plastics. After gaining insights to bio-based plastics, they welcomed the concept of bio-based plastics and reflected that it could strengthen the circular economy, mentioning closed-loop systems, specifically in the context of diminishing fossil fuels.

I think it's a step in the right direction. (S #4)

It would have to be better all you hear is production of oil and use of oil and going away from fossil fuel and that's very important. (C #3)

Research has shown that the bioeconomy needs to imbibe the principles of circular economy (Aguilar et al., 2018). With the circular bioeconomy in mind, incorporation of slaughterhouse and animal waste into manufacturing of bio-based plastics has been per-

Table 3
Questions raised by participants about sustainability and bio-based plastics

Topics	Questions
Consumers	
Sustainability	Where is the sustainability? What if we use more wood than plastics for making chairs?
Recyclability	Are bio-based products recyclable?
Compostability	Would it be compostable? When you stop using it what would be left behind?
Definition	How much is the percentage of bio-based raw materials for a bio-based plastic?
Students	
Production	Will there be enough land?
Manufacturers	Is Lego™ not moving towards bio-based polymers, aren't they?
Costs	What if we increase the production costs due to change in feedstock?
Energy	How much energy does it take to produce bio-based plastics?
Durability	Would it stand the test of time?
Structural integrity	Can it be on a shelf for 6 months? Like petroleum ones can. Do these 'new plastics' have structural integrity compared to PET?
Environmental professionals and plastic processors	
Production	Do you take land away from food production and put that towards plastic production?
Recyclability	So bio-based plastics can be put through with traditional plastics?
Complexity for recycling	Is it not an increased layer of complexity for the public?
Increased use	Are we not incentivising more plastic waste by producing bio-based plastics?

formed (The James Dyson Award, 2019). Thus, we were keen to explore perceptions towards the use of slaughterhouse and animal waste for manufacturing bio-based plastics for food packaging. The environmental professionals and plastic processors said that they know that food packaging has to meet food safety standards and so it will be safe.

I would have no issue because it's going to have to be processed into a form that is safe. (E #9)

Most of the students and consumers did not report any grave problems with this.

I personally don't have any ethical reasons to oppose these. (S #6)

It would not bother me to buy something that was animal based. (C #5)

In contrast, vegetarians and vegans among both students and consumers did not agree with the use of slaughterhouse waste for food contact products. Some of the vegan participants indicated that use of animal waste may cause increased killing of animals and frowned upon this option. Furthermore, there was a set of participants without any dietary restrictions but who still demonstrated concerns about use of animal waste in bio-based plastics because of shelf life or because of feelings of unease about some materials (even if they knew the materials were safe).

I would not buy that. (C #2)

Part of me looks at it and that my stomach would ache. I only started thinking about it ten years ago, that where my plastics came from and only recently I am really thinking what the impact of that is. I am ok with eggshells and feathers, some of the other stuff, my instinctive response with that is that I slightly feel uneasy. (C #1)

We next asked for participants' views on the use of bio-based plastics for non-food contact products. The environmental professionals and plastic processors did not show any concerns about the presence of bio-based feedstock in plastics and said that they would prefer a product made from waste. However, some of the environmental professionals and plastic processors showed concerns over the durability of bio-based plastics and were also interested in the difference between bio-based and conventional plastics in terms of life cycle impacts.

I would like to see the comparison between the production of a desk from fossil fuel and bio-sourced plastics just in terms of the process, energy consumption and how it works – things like that. I think the people that are going to care about that [bio-based plastics] will want to see that as well. (E #2)

Some students said that they would feel proud of themselves if all their furniture was made of bio-based plastics, as they could show it off to their friends and be more environmentally friendly. Other students reported that if the non-food contact plastics have the same durability as conventional plastics and could stand the test of time reasonably, they would not mind.

All my furniture is bioplastic would be probably more attractive than unattractive to people now. If you get a green stamp you can pat yourself on the back because 'hey I'm helping the environment!'. (S #5)

The consumers confessed that they had not paid attention to the raw materials used for plastics and that they do not specifically go into supermarkets looking for bio-based plastics. Students and consumers preferred the use of bio-based plastics for non-food contact products over food packaging. Vegan consumers mentioned that increased demand for bio-based plastics may lead to detrimental impacts on animals or opening of more chicken farms and so they would not purchase bio-based plastics even if they were not concerned about food contamination.

I think a change of mind-set in that direction that [there] are lot of people are becoming conscious of what they are buying. I think if you are already in the mind-set, it would affect you, but you wouldn't purposely buy a chair that is made from biomass. (C #2)

3.3. Theme 2: Willingness-to-pay for bio-based plastics

As discussions were becoming more detailed, the issue about prices was discussed several times. It was very interesting that even after taking into account the challenges linked to food security and recycling of bio-based plastics, the majority of the environmental professionals and plastic processors found it acceptable to pay higher prices for bio-based plastics.

I do not have a problem with that [high prices]. (E #6)

Students said that they would not be happy with higher prices for bio-based products. However, this is not to say that the students were not interested in bio-based plastics. In fact, this group had some of the most enthusiastic participants and came up with creative suggestions. The students displayed clear intentions to purchase bio-based products with pro-environmental attributes, but they mentioned that the prices of products acted as a barrier in general. As the students became more and more involved in the discussion, they suggested that they would be happy to pay extra only if there was assurance that the increased prices would directly help the manufacturers.

If you're buying a week's worth of food, that's going to add up very quickly. (S #8)

The majority of the consumers and some environmental professionals and plastic processors reacted negatively to the idea of paying more and said that multinational companies are only going to use this money for increasing their profits and that it would be

nothing more than a marketing scam. That said, the younger consumers (age: 25-35) exhibited that they are more aware of environmental issues and are ready to change their habits about plastic purchase.

People just want to spend as little as possible. (C #5)

For me the benefit would have to be reasonable. I would pay 20 pence more for plastic that would disappear. (C #1)

3.4. Theme 3: Opinions on the integration of bio-based plastics

We explored whether actual samples influenced participants' perceptions of bio-based plastics and the recorded responses are presented in **Supplementary material: S6 and S7**. Following this we asked about the prerequisites for integration of bio-based plastics. Although the environmental professionals and plastic processors raised the challenges of 'side-effects', such as food security, landscape management, contamination of recycling streams and anaerobic digestion, throughout the discussion, they mentioned that there is necessity to drive innovation in the bio-based plastics sector. However, they also concluded that there has to be proper labelling to prevent confusion with recycling, and that we have to be wary of knee-jerk reactions.

It may provide a longevity in the long-term views and if oil is more controlled. Then it gives you future alternatives and something like necessity to drive innovation. Great idea, great application! (E #2)

I'm slightly more worried after today that it'll be a knee-jerk reaction and that it'll be the wrong solution. Are we not incentivising more plastic waste by producing bio-based plastics? (E #4)

The students said that there should be an educational side to it, such as proper labelling to aid and assist in the end-of-life management and recycling of bio-based plastics.

I have a lot of friends who, well it depends what day of the week it is - what bin it goes in. Quite quickly it'll be – it'll go into the blue bin if the blue bin is a bit empty. (S #4)

The consumers showed scepticism, cynicism and a general sense of fear about the new products. They mentioned that plastics can be managed more with a top-down approach rather than a bottom-up approach and said that prices are not a very linear thing. The consumers also indicated that the participation in the focus group led them to pay attention to issues that they normally do not pay attention to.

I say it is not bottom-up problem, top-down. We are focusing on consumption and not on production. It is funny how just only five-six [handful] of companies control our food. (C #1)

You know, when we were young, for every new thing, we would be told that it will solve our problems. It never happened. I do not want to think thirty years from now, that it was a bad decision. (C #1)

4. Discussion

The focus groups (n = 25) set out to investigate stakeholders' perceptions of bio-based plastics and found a range of concerns and opinions among the three target groups of environmental professionals and plastic processors, students, and consumers. The following section discusses the findings of the focus groups in relation to knowledge, environmental and ethical concerns, pricing, product evaluation and practical implementation. We conclude by providing recommendations to inform the development of the sector.

4.1. Comparison of stakeholder perceptions

4.1.1. What's in it for me?

There was an underlying theme in all responses when the participants were discussing products. Almost all the recorded responses were about 'What's in it for me?'. This means that people buy what they see, need, and regard as beneficial (Phillips and Corkindale, 2002). This underlines that products are assessed in the context of personal benefits. The environmental professionals and plastic processors talked more about the recycling of starch-based plastics and food security issues. On the contrary, students were concerned about structural integrity, texture, thickness and transparency. Consumers were mostly accepting and appreciated the versatility of bio-based plastics. However, it is interesting to note that consumers also used the highest percentage of words with negative associations (**Fig. 2**) and reacted with feelings and emotions towards plastics in the wider context. It has been reported that plastics are increasingly perceived as problematic by consumers (Adane and Muleta, 2011), an observation that is further confirmed by the association of 'plastic' with 'sustainability' or 'waste' on social media (Richardson et al., 2016). This is in line with the findings of Dilkes-Hoffman et al. (2019b) where an investigation of consumers' reactions to plastics showed that 38% of the analysed words were associated with negative connotations. We recorded that focus group participants with the lowest level of existing knowledge displayed the strongest reactions in terms of emotions, whereas participants with a higher level of existing knowledge reacted in a more measured way, responding with neutral emotions towards plastics.

4.1.2. Green values, greenwashing and the impact on willingness-to-pay

Today's small production scales and industry's lack of experience with the production of bio-based plastic results in higher prices for these plastics, thus it is crucial to understand willingness-to-pay and the reasons behind this. Of the three stakeholder groups, the environmental professionals and plastic processors, with the highest level of existing background knowledge, showed a higher willingness-to-pay, as they regarded plastics as convenient and valuable, and bio-based plastics as a step in the right direction (**Fig. 3**).

Participants in other groups with specific background knowledge and a strong attachment to environmental protection also tended to show higher willingness to pay. This was illustrated by the vegans in the consumer group, who said that price was not a concern as long as their money goes to a good cause. Consumer purchasing decisions are also influenced by perceived consumption value (e.g. sustainability, safety) of green products, as documented for plastics by Herbes et al. (2018), for green hotels by Wang et al. (2018), for batteries by Choi et al. (2020), for bioplastic based rain jackets by Klein et al. (2020), and for sand toys made of bio-based plastics by Scherer et al. (2017). Furthermore, the relationship between (green) consumption values and intentions to purchase bio-based products may be mediated by positive attitudes/emotions towards a brand and may occur in individuals with stronger green values (Reinders et al., 2017). A positive green image leads to payment of a green premium by consumers for bio-based plastics (Boz et al., 2020; Martinho et al., 2015).

Lower purchasing power was also seen to have an impact on willingness-to-pay, with the youngest participants (undergraduate and postgraduate students) having the lowest willingness-to-pay. Students also showed a lack of trust in government-imposed laws such as the plastic bag levy, but interestingly reported that they would be willing to pay more if it helped industry. On the contrary, the majority of consumers reacted in shock that manufacturers may need to increase the prices of the products to fund the transition from fossil-based production to bio-based processes. There was a considerable amount of cynicism among consumers about industry actually using the additional payment for production of bio-based plastics. The consumer group in general displayed distrust in industry and reflected that using bio-based plastics would only be a marketing strategy to increase prices of products.

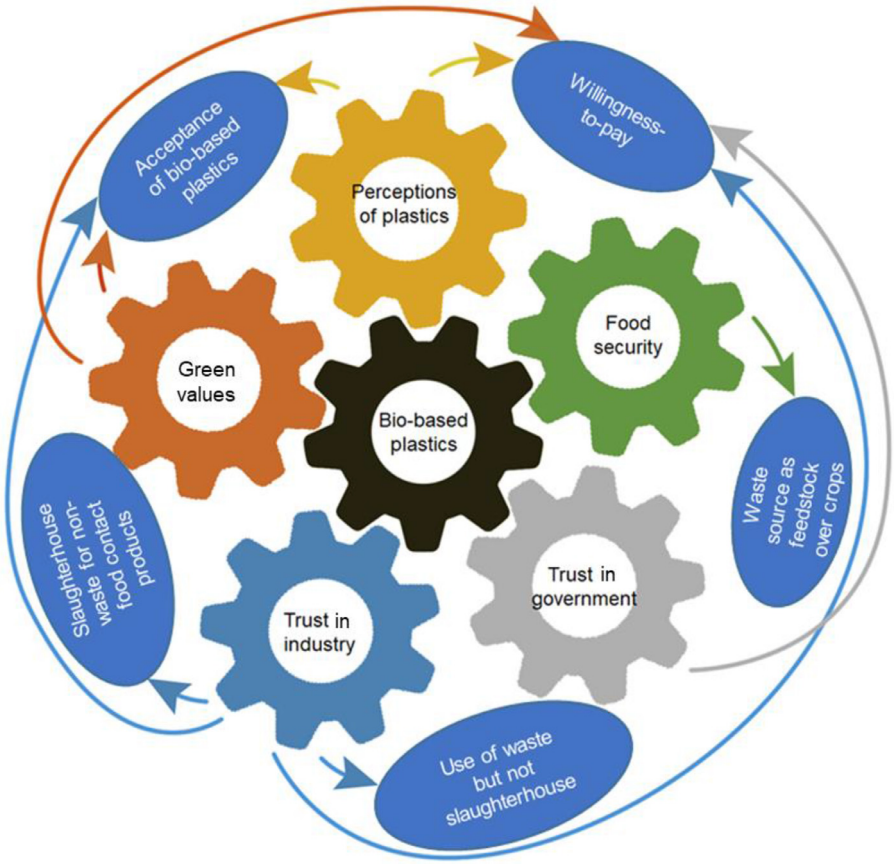


Fig. 3. Schematic showing interaction of factors affecting stakeholders' perceptions of bio-based plastics.

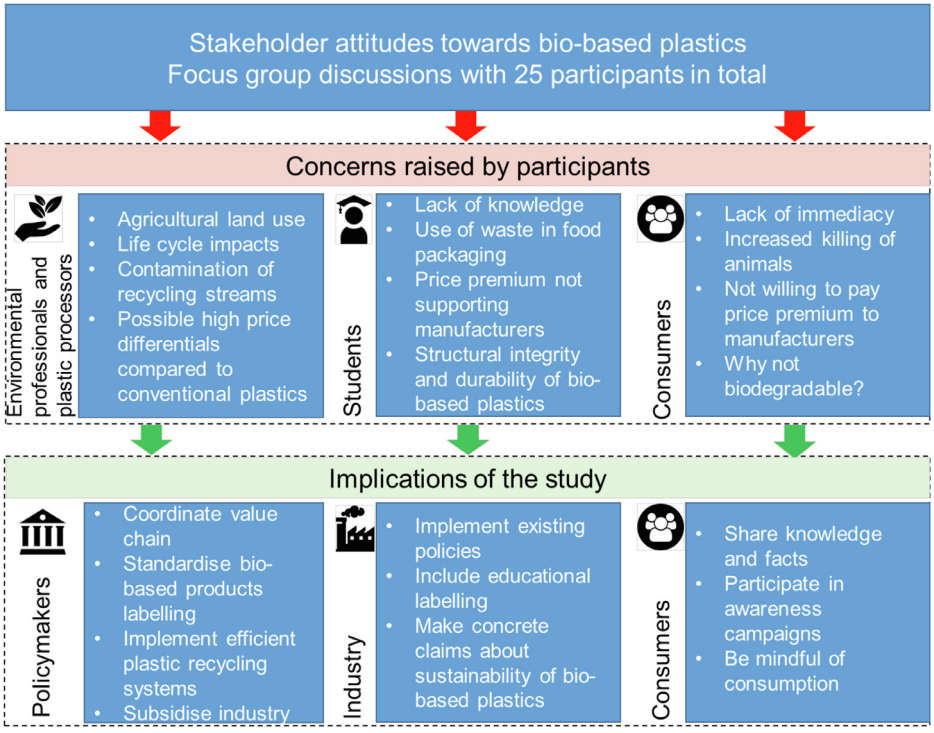


Fig. 4. Schematic showing concerns raised by participants and implications of the study.

These doubts could be due to: (1) Concerns about previous voluntary industry commitments to a range of issues that are criticised for not being complete and all-inclusive (Carrington, 2016). If voluntary efforts are not convincing, this becomes a sensitive issue that is later reflected in willingness-to-pay. The research undertaken by Carlos and Lewis (2018), Du et al. (2020), Gosselt et al. (2019), and Pomering and Johnson (2009) concluded that consumer scepticism towards firms that claim to work towards sustainable development goals is intensifying and that the effects of greenwashing can be harmful for the public's evaluation of a company; and (2) A preference for low priced products by the consumers. Another study segregating green consumers also identified consumers with less interest in environmentally friendly products; these consumers were described as price-oriented consumers or conventional buyers (Kunamaneni et al., 2019).

4.1.3. Raw materials and the use of slaughterhouse waste

After some discussion, it was evident that participants appreciated the role of bio-based plastics in providing alternatives to fossil-based plastics and specifically remarked that fossil fuels are a finite resource. The consumers, for example, were largely comfortable with the starch-based plastics and referred to them as 'acceptable', 'brilliant', 'fine', 'good', and 'great'. They also mentioned other aspects of the products, such as the appearance, usability, production processes, expensiveness, versatility, price and proportion of biomass in the new material (e.g. use of corn in bio-based plastics). The recorded reactions and discussions to the actual products implied they were largely accommodating of the texture and feel of bio-based plastics (**Supplementary material: S7**). However, our study also demonstrated that interested stakeholders tend to have stricter requirements for bio-based plastics than for their fossil counterparts. Participants from all focus groups said that bio-based plastics should be produced using waste from another process to prevent pressure on agricultural land and avert food security issues (**Fig. 3**). This is in line with studies showing that agricultural biomass production for bio-based plastics could lead to environmental degradation, for e.g. diversion of arable land from its original purpose, soil erosion, eutrophication of water sources, or fragmentation of habitats (Harding et al., 2007; Narodoslawsky et al., 2015; Piemonte and Gironi, 2011).

Despite the general consensus among the groups that the use of wastes for bio-based plastics production is a positive step, there were differences in opinions regarding the type of waste considered acceptable and the end use of the plastic, e.g. packaging used for food or non-food applications. The environmental professionals and plastic processors displayed an acceptance of products from waste and an inclination towards circular models. Although initially unsure, after explanations the student group welcomed the use of waste products for a more closed-loop approach. Environmental professionals, plastic processors and most of the student group believed that products are not put on the market unless they are checked for food safety and thus found it largely acceptable for wastes, including slaughterhouse waste, to be used in the production of bio-based plastics. This suggests that greater understanding of bio-based plastics may help alleviate safety concerns. Relatedly, Herbes et al. (2018) found that German consumers are more inclined to use biomethane-based packaging compared to consumers from the USA and France. This was attributed to the fact that biogas plants are more prominent in Germany compared to the other two countries, and therefore consumers' knowledge of by-products from biogas plants is higher, which may support greater acceptance of this type of packaging.

The consumer group was particularly sensitive to the idea of using slaughterhouse waste for bio-based plastic production. Members of the consumer group rejected products due to an 'animal-waste unpleasant' notion and there were some consumers who lacked trust in industry and mentioned that slaughterhouse waste should only be used for non-food contact products due to perceived hygiene issues. Some students also opposed the idea of using slaughterhouse waste products for food contact products. The special sensitivity of consumers to food issues has been reported in other science communication areas such as genetic modification, food allergies and eating out (Ju et al., 2015; Sloan and Powers, 1986).

The findings suggest that ecological worldviews and the importance of environmental protection in the value system of stakeholders may influence perceptions towards bio-based plastics. Vegan consumers had the strongest reservations about bio-based plastics from slaughterhouse waste for all types of products (food contact applications and non-food contact products). We noted that the same consumers who expressed pro-environmental views also found the use of slaughterhouse waste for incorporation in bio-based plastics unacceptable as it could lead to increased killing of animals (**Fig. 3**). This complicates the introduction of bio-based plastics as a solution to supporting a closed-loop system, as bio-based plastics may be perceived as a threat to animal welfare. Fan et al. (2019) found that consumers, who adopted a diet perceived as an environmentally responsible choice (e.g. vegetarianism), demonstrated stronger pro-environmental values and increased interest in green hotels. However, as the current findings suggest, where bio-based plastics with slaughterhouse waste as feedstocks are concerned, there is an added layer of ethical assurance that needs to be established relating to animal (as well as human) welfare.

4.1.4. Disposal of plastics

There were different perspectives among the stakeholder groups on end-of-life and disposal of plastics; this was a particular focus for the consumer group, which displayed enthusiasm for the topic. Some consumers pointed out that they would be willing to pay more for biodegradable plastics, while some students expressed interest in recyclability of bio-based plastics. The possible explanations for consumer interest in the end-of life attributes are: (1) It is this stage in the life of the products that consumers interact with most directly, as they have to make a decision on disposal; (2) Regional and industry-led recycling systems have been gaining momentum in the UK which may enforce the urgency of recycling in consumers' mind-sets. A recently published review study on tackling plastics' problems also highlighted the importance of recyclability and biodegradability of plastics to consumers (Heidbreder et al., 2019). However, despite the interest of the consumer and student groups in recycling and biodegradability, environmental professionals and plastic processors raised concerns about the ability of the public to properly manage waste within the current system. The environmental professionals and plastic processors noted that the public has neither the understanding nor the inclination to properly sort plastics into the required waste streams.

4.2. Implications for the bio-based plastics sector and recommendations

Based on stakeholder perspectives and concerns, a series of recommendations are made to support the development of the bio-based plastics sector (**Fig. 4**).

4.2.1. Production and feedstocks: Education and labelling

The students and consumers did not show much prior knowledge of bio-based plastics. A similar lack of knowledge on the topic of bioplastics has also been reported by Blesin et al. (2017) and was observed in a recent study of consumers' perceptions of bio-based products in five European countries (Sijtsema et al., 2016) and in

earlier research on bioplastics in the UK (WRAP 2007). However, participants did show awareness of the end-of-life implications of plastic products (particularly evident in the willingness-to-pay responses), which indicates that focusing on end-of-life attributes such as biodegradability and recyclability could be a communication strategy for industry and manufacturers, particularly in the shorter term.

Although some in the consumer and student groups had previously not reflected on the implications of plastics being manufactured from agricultural or petroleum feedstocks, after discussion, students and consumers acknowledged that bio-based feedstocks are a step in the right direction and there is a requirement for these products. Some environmental professionals and students mentioned that the energy consumption and overall impacts of fossil-based vs bio-based plastics should be given on product labels. It would therefore be beneficial to inform consumers of the environmental impacts of production processes and beginning-of-life implications. To encourage consumers to purchase such products, clear communication and labelling are needed. Wurster and Schulze (2020) suggested that missing information on sustainability poses a barrier to the adoption of sustainable products, while Bleda and Valente (2009), Peuckert and Quitzow (2017), and Teisl and Roe (1998) suggest that labels are imperative in ensuring, verifying and communicating sustainability aspects. By providing information on the environmental characteristics of bio-based products, such as life cycle impacts and percentage of bio-based raw materials, consumers can select a product based on features that would otherwise go unnoticed.

Even though the need for transparency on the life cycle impacts of bio-based products among consumers has been highlighted, it is worth acknowledging that this could be very complex and not automatically transparent (Lynch et al., 2017). Labelling should help consumers rather than confuse them. Coghlan (2011) points out that consumers are finding it challenging to differentiate between companies dedicated to making a difference and those that are using a green curtain to conceal dark motives, cynicism that was reflected in our focus groups. This implies that the usefulness of labels hinges on compliance with national and international environmental regulations (Peuckert, 2014), and substantiation of claims by easily accessible information and reliable third-party or neutral organisations. Important features of such green quality systems include: (1) Metrology to provide measurements and methods for reliable environmental performances, (2) Standardisation using relevant reference units, (3) Certification and inspection for showing compliance with environmental regulations and legislations, and (4) Accreditation by ensuring the competence of certifiers and testing laboratories (more details in World Resources Forum, n.d.).

When developing green standards, policymakers should be mindful that the bio-based industry is still unrecognised by consumers (Kainz, 2016). This is of particular relevance when considering potentially controversial feedstocks such as slaughterhouse waste. Opinions such as those recorded in the consumer group, that using slaughterhouse waste could lead to 'increased killing of animals', might present communication challenges to the industry. From our experience with the focus group, recommended strategies include informing consumers about how slaughterhouse waste is currently managed and implications for the circular bioeconomy, and answering concerns with sincerity and transparency. Active organisation and participation in knowledge sharing and awareness campaigns by consumers can result in favourable outcomes for bio-based policies and desirable products for themselves (European Commission 2017). This will also ensure that developments in the bio-based plastics sector are not only shared 'with the public' during product marketing, but are also 'by and for the public'. Moreover, policymakers should ensure that industries, manufacturers and government organisations work together in the value chain to prevent a 'shift of responsibility' amongst the various stakeholders.

4.2.2. End of life: Recycling, biodegradability and disposal

Local councils are under increasing pressure from statutory bodies to increase recycling rates (Gent, 2020). There is also growing concern about recycling of plastics within national boundaries, especially after China's Green Fence Campaign and National Green Sword Programme (Brooks et al., 2018). Considering this, the introduction of bio-based plastics which are not compatible with current plastic recycling streams is a concern (**Table 3**), as it may lead to an increase in plastic waste. The difficulty and expense of sorting of mixed plastics consisting of fossil-fuel based and bio-based plastics can impact on collection rates and recycled material quality, plummeting the already low level of plastics recycling percentages (Alaerts et al., 2018; Ducat, 2018; Sherwood et al., 2016).

For successful mechanical recycling of bio-based plastics, there is a need for consumer awareness about sorting various plastics and providing a well-oiled system of collection and recycling (Ducat, 2018), an opinion echoed by environmental professionals and plastic processors during the focus groups. Chemical processes could also alleviate the problems associated with recycling mixed plastic streams containing both fossil-based and bio-based plastics. The recovery of building blocks using selective depolymerisation of plastics for repolymerisation to the original polymer is possible, but future research is required to address the detrimental impacts on material properties currently experienced (Hatti-Kaul et al., 2020).

An alternative route to recycling is biodegradability. From an environmental sustainability perspective, biodegradable bio-based plastics are attractive when biodegradability offers co-benefits and/or provides direct functionality. For example, in the agricultural sector, biodegradable bio-based plastics can reduce litter and decrease the release of non-biodegradable plastics, which may not be completely removed after use (Odegard et al., 2017), such as edible silage wrap for cattle. However, biodegradability should not be considered a foolproof solution to the problem of littering (Thomlinson, 2019), which should be tackled by informing citizens. The continual communication with consumers is important to avoid unintended consequences/perverse impacts, e.g. people may use more plastics because they know it's not going to landfill or dispose of plastic waste incorrectly (Brizga et al., 2020; Krieger, 2019; Taufik et al., 2020). Thus, consumers and policymakers have a responsibility to be mindful of over-consumption because alternatives to landfill such as biodegradability or recycling are much more effective if there is less waste in the first place.

4.3. Limitations and avenues for further research

The current research is based on participants from Northern Ireland, and it is important to note that the international transferability of results can be influenced by sociodemographic and cultural differences between various nations (Klein et al, 2019). Moreover, due to time and resource constraints the focus groups with consumers and students were not repeated. This said, there was consistency observed in the key messages captured. To build on the current findings, there is ongoing opinion survey research on recycling of plastics and bio-based plastics, and the survey has accrued 370+ respondents in Northern Ireland. The present research included opinions of the plastic processors from a plastics processing facility, however future research would benefit from including more participants from plastics manufacturers. It would also be interesting to investigate the opinions of students from non-science, technology, engineering and mathematics (STEM) disciplines.

Samples of conventional PET and starch-based plastics were provided to evoke responses about texture, colour, transparency

and various other design aspects. However, there are various other bio-based plastics, and future research could therefore benefit from demonstrating bio-based plastics from other renewable sources such as cellulose, fish waste and poultry waste. It would also be interesting to provide the participants with more complex bio-based plastic products to understand their interaction with products. Past research on packaging shows that participants interact with products in terms of healthiness and sustainability (Cho and Baskin, 2018; Magnier et al., 2016).

5. Conclusions

The transition to the bioeconomy needs a stakeholder-oriented approach, considering that its success depends on technological feasibility, economic viability and social desirability. Stakeholder focus group discussions were organised, in which starch-based monolayer and multilayer and polyethylene terephthalate (PET) samples were presented. The results suggested that consumers lack familiarity and immediacy about bio-based plastics. Participants in all groups (environmental professionals and plastic processors, students, and consumers) recognised that fossil fuel savings could be achieved through the use of bio-based in place of conventional plastics. However, due to the challenges related to food security and agricultural land management, all the participants had preference for waste-derived feedstocks. Slaughterhouse waste as feedstock was not acceptable among vegan consumers for either food packaging or non-food contact products. Some students raised concerns about the use of slaughterhouse waste for bio-based plastics for food contact applications. There was also a considerable amount of cynicism towards the industry resulting in lower willingness-to pay among the majority of consumers. Students showed lowest willingness-to-pay, though this could be due to prices acting as a barrier in general for many products, however, they were willing to pay if it was ascertained that the price differential would directly help manufacturers. When presented with samples of both bio-based and conventional plastics, stakeholders found bio-based plastics acceptable. The findings from the present study suggest important implications such as:

- Policymakers should ensure standardisation of bio-based products and labelling. There is a clear need for coordinating the value chain to avoid a ‘shift of responsibility’ among various stakeholders.
- Industry could benefit by informing consumers of environmental impacts of production processes such as beginning-of-life implications using life cycle assessment parameters. This should be incorporated into information provided on labelling using standards from neutral organisations.
- Finally, we should not forget the role of consumer behaviour in the bigger picture of plastics use and disposal.

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.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.spc.2020.12.015.

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