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# Bio-Based Materials Riding the Wave of Sustainability: Common Misconceptions, Opportunities, Challenges and the Way Forward

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**Abstract:** Solid waste disposal, particularly of plastic and rubber, significantly impacts the environment and human health; thus, encouraging consumers to u sustainable alternatives is essential to ensure a resilient future. In recent decades, bio-based material research has primarily focused on bioplastics and, accordingly, current knowledge of alternative sustainable materials (such as biorubber) is fragmented, with consumer misconceptions posing a key challenge. This paper provides a comprehensive overview of the fundamentals of bio-based materials, in addition to common misconceptions about them. The findings of a public survey that aimed to assess consumers' attitudes towards, as well as their awareness and perceptions of, conventional and sustainable alternative materials, particularly oxo-biodegradable rubbers, are also reported in this paper. Despite their unfamiliarity with the terms 'bio-based' and 'oxo-biodegradable', most respondents had a positive view of bio-based products and expressed an interest in reducing their use of conventional products in favour of sustainable alternatives. The results also revealed that consumers are willing to spend more on sustainable alternatives because they are aware of the environmental issues associated with solid waste. This study provides new insights into knowledge gaps and challenges that must be addressed to promote the prudent use of sustainable materials in a fast-changing world.

**Keywords:** bio-based materials; consumer behaviour; environment; oxo-biodegradable rubber; synthetic materials; sustainability; waste management

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## 1. Introduction

The overall mass of synthetic products, which includes everything from concrete structures and metal cars to rubber gloves and plastic bottles, is predicted to outweigh the mass of all life forms on Earth, which has been estimated at around 1.1 trillion metric tonnes in the early 2020s. Known as the anthropogenic mass, the amount of synthetic (or artificial and conventional) materials continues to expand exponentially, heralding the Anthropocene period, in which humans are regarded as the dominant driving factor that shapes the world [1,2]. Various anthropogenic activities, such as agriculture and urban growth, are known to have an impact on climate change, ecosystem services, and biodiversity loss [3]. As humanity's need for materials and resources grows, negative environmental effects such as pollution and soil erosion will become more severe [3,4]. As a result, it is critical to explore sustainable alternatives to synthetic materials in order to ensure a long-term future for humanity. In a rapidly changing climate, the utilization and manufacturing of biodegradable, bio-based products, such as eco-friendly plastics, can help achieve multiple United Nations Sustainable Development Goals (SDGs) [5,6].

Plastics, the most widely used material on the planet, have transformed daily life and revolutionised the healthcare industry by providing low-cost medical devices and disposables [7]. Plastics' reliance and convenience, however, come at a cost, with approximately 60% of the over 8 billion tonnes of plastic produced since the 1950s ending up in the environment [8–10]. Because conventional plastics, such as poly (ethylene terephthalate) (PET), are extremely resistant to natural biodegradation processes, they are regarded as large-scale pollutants that devastate both terrestrial and marine ecosystems [10–12]. A recent study on microplastics (plastic fragments less than 5 mm in length) has painted a broad picture of the negative impact of plastic pollution on the marine biome, in which these tiny pieces of plastic are replacing food in the diet of zooplankton, reducing their consumption and export of particle-bound organic carbon, which disrupts global ocean oxygenation [13]. Because of the coronavirus (COVID-19) pandemic, the numerous uses of single-use plastic products such as gloves and masks are likely to exacerbate plastic pollution [14].

While plastic pollution is regarded as one of the most pressing challenges of the twenty-first century, increasing demand for products made from other synthetic materials, particularly rubber, has also been reported to be weakening ecosystems and biodiversity, owing to ineffective waste management [12]. Rubber, similarly to plastic, is essential to human life, but only a small portion of its slow-degrading waste is recycled. Much of the rubber waste ends up in landfills, where it leaches potentially toxic substances into the soil and water, endangering the survival of various terrestrial organisms such as plants and animals [15,16]. Although there is increased attention on rubber utilisation as an environmental issue, which is supported by science, there is a gap in documenting and understanding the general public's attitudes and awareness towards rubber products and environmentally sustainable alternatives that merit consideration [17]. Given that a large portion of rubber is used in consumer applications, public opinion is an important determinant of whether a sustainability initiative will be successful.

Sustainability issues and challenges associated with synthetic materials remain largely unresolved, even though some emerging sustainability initiatives have been launched to transform the multibillion-dollar rubber and plastics industries [18,19]. The classic 3R Initiative (Reduce, Recover, and Recycle) in waste management is one notable example, which has now been expanded to 7Rs (Reduce, Recover, Recycle, Refuse, Reuse, Repair, and Re-gift) [20]. It is also worth noting that the use of eco-friendly materials such as bio-based and biodegradable has been established as a strategy to aid in the achievement of a suite of SDGs in the face of climate change, such as SDG9 and SDG12, which target industrial innovation and infrastructure and responsible consumption and production [6], respectively.

According to Pahl et al. [21], for any changes in the polymeric material system to be successful, alternative materials must be not only technically and economically viable, but also socially acceptable. Because the published literature on public awareness and attitudes toward synthetic materials and their alternatives, particularly rubbers, is currently scarce or fragmented, perplexing terms such as bio-based, biodegradable, and compostable have led to confusion and misplaced optimism among the general public [22–24]. The aims of this review are, therefore, to highlight common misconceptions about the terminologies used for renewable resources in synthetic materials, as well as to provide critical insights into the general public's knowledge, awareness, and attitude toward these sustainable alternatives to synthetic products via a public survey.

## 2. The Ubiquitous Fallacies of Bio-Based Materials

Over the last decade, there has been a remarkable surge in the zero-waste bandwagon all over the world. Plastic-free shopping has become the norm in many parts of the world, and plastic-free swaps are encouraged and carried out in a variety of ways, ranging from the use of natural plastic alternatives (such as fibre cloth) to eco-friendly alternatives (such as bioplastic) [25]. Bio-based materials have come a long way, but there are still

many challenges ahead. Despite the fact that increasing global awareness and changing public demands are prompting more research on sustainable product development, there is confusion and misinformation about bio-based materials, particularly bioplastic, which may stymie the progress of a promising industry geared toward a sustainable future [23].

### *2.1. Bio-Based Materials Falsely Deemed Biodegradable*

Bio-based materials, on the whole, are not biodegradable (Figure 1). Bio-based plastics such as Bio-Polyethylene (Bio-PE) and Bio-Poly (ethylene Terephthalate) (Bio-PET) are known to be non-biodegradable. Much of the public confusion surrounding bio-based plastics stems from the use of the term "bioplastic", which is misrepresented on the labels of many plastic products [26]; this frequently leads to waste disposal issues, where bioproducts are not properly sorted at their end-of-life, resulting in significant environmental issues. Bioplastics, in general, refer to a diverse family of plastic materials that are either bio-based, biodegradable or have both properties (Figure 1) [27]. A bio-based plastic is typically made from renewable resources, primarily plant biomass, and may have the same durability and properties as conventional plastics.

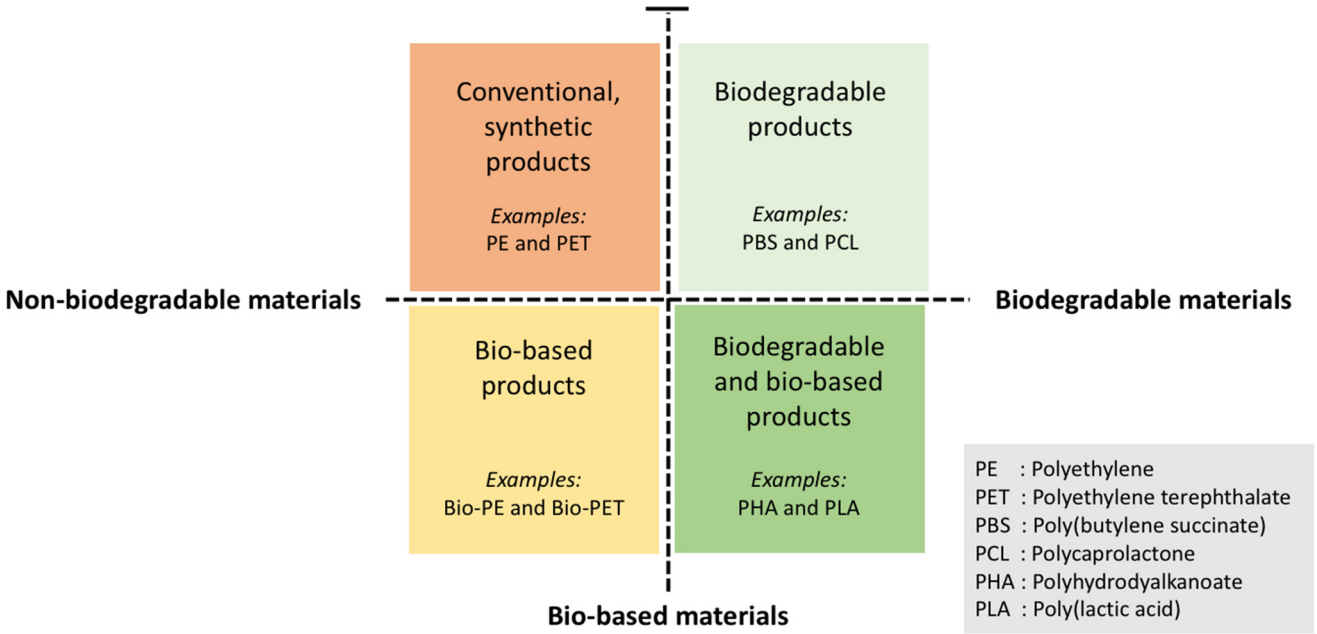



**Figure 1.** Examples of plastic products made from different materials.

A biodegradable plastic, on the other hand, is a polymeric plastic or material that is capable of decomposing into various forms such as methane ($CH_4$), carbon dioxide ($CO_2$), water ($H_2O$), inorganic compounds, or biomass via a predominant mechanism involving enzymic action by microorganisms [28,29], and this can be measured using standardised tests that reflect the availability of appropriate disposal conditions (suitable temperature and relative humidity) in a specific period of time [30,31]. Examples of biodegradable plastics include polybutylene succinate (PBS) and polycaprolactone (PCL) (Figure 1), which contain chemical structures that permit biodegradability. It is important to note that several bioplastics are both bio-based and biodegradable [32], such as polyhydroxyalkanoates (PHA) and polylactic acid (PLA), and these are the bioplastics that can provide solutions with novel functionalities, such as compostability, durability, and barrier properties [33].

### *2.2. The Blurring Line between Composability and Biodegradability*

Another common public misconception is that all biodegradable materials are compostable, which is untrue. In a composting environment, compostable materials biodegrade,

producing $CO_2$, $H_2O$, inorganic compounds, and biomass [34]. While all compostable materials are biodegradable, some biodegradable materials are not easily compostable due to the presence of visible or toxic residue. Certain scientific standards and criteria, such as biodegradability, disintegration, and toxicity, must be met in order for biodegradable materials to be labelled compostable in some countries, such as the United States (non-toxic to plants) [29,35]. Table 1 shows the differences between these materials, as well as oxo-biodegradable material, a significant polymeric material that evolved in the 2010s [36,37]. These terms are frequently used interchangeably, but they are not synonymous.

**Table 1.** Comparison of compostable, biodegradable, and oxo-biodegradable materials.

| | Compostable | Biodegradable | Oxo-Biodegradable |
|---|---|---|---|
| **Definition** | Materials that break down into carbon dioxide, biomass, and water within a specific time frame under suitable composting conditions | Materials that break down into carbon dioxide, biomass, and water under the presence of microorganisms, bacteria, and fungi | Materials that break down into smaller pieces under the presence of heavy metals or other catalysts |
| **Residue** | Leaves no toxic or visible residue | May leave residue in the environment if toxic ingredients do not break down | Leaves heavy metals or other toxins in the environment |
| **Property** | Can break down completely in nature | May take a long time to break down, depending on the disposal environment | Complete breakdown and biodegradation still have to be proven |
| **Nutrients** | Releases nutrients to the soil | Does not provide nutrients to the soil | Does not provide nutrients to the soil |
| **Recyclability** | Not recyclable | Recyclable | Recyclable |

Oxo-biodegradable refers to materials that have been mixed with pro-degradant additives (primarily metal salts) to enhance their ability to undergo oxidative degradation, and subsequently mimic the biodegradation process. These materials first degrade quickly into smaller pieces via oxidative degradation, but not at the polymer or molecular level. Their residues are released into the environment until they are completely degraded via biodegradation [38].

## 3. Current Challenges in Developing Bio-Based Materials as the Preferable Alternative for Sustainable Waste Disposal

To establish bio-based materials as a viable option for sustainable waste disposal, industry players and the general public need to understand and recognise that not all bio-based materials are biodegradable in the same way, and each has its own set of flaws. Biodegradable materials are frequently presented as a way to help reduce the amount of waste in a specific country or region, despite the fact that only a small portion of these materials are compostable or can fully degrade [23,39]. Misleading information or claims about the false benefits of certain bio-based material-derived products will delay or impede efforts to improve litter control and divert appropriate material streams away from landfills. Littering should ideally not be encouraged for any type of waste, and educational measures should be implemented to raise awareness about proper waste management, disposal, and recycling methods [11,23]. It is worth noting that commodity plastics (such as PE and PET) can be made from renewable resources, with bioethanol being a prime example. Bio-PE, for instance, has been produced on a large scale in many parts of the world.

Succinctly, biodegradation can occur under a variety of conditions (such as the presence of bacteria or fungi and the availability of oxygen) in a variety of natural and artificial environments with varying levels of influencing factors such as timeframe, temperature, and relative humidity [40]. To avoid making false claims about their products, the bio-based materials industry should ensure that all of the different factors have been taken into account and thoroughly examined before making any substantial claims about the compostability or biodegradability of their materials. Furthermore, there is little to no evi-

dence to confirm that pro-degradant additives will promote or enhance the biodegradation of bioplastics such as PE and PET polymers [41,42]. Compostable materials are the most sustainable of the bio-based materials discussed, and they may be the most important tool for zero waste programmes around the world.

One of the most important roles of researchers is to ensure that the development of bio-based materials is socially acceptable in addition to being technically and commercially viable in order for them to be established as sustainable materials, which could be a huge challenge given that public awareness is still largely unexplored. There is a paucity of literature on public understanding and perceptions of synthetic materials and their alternatives [21]; therefore, we conducted a survey to assess the general public's knowledge, awareness, and attitudes about these sustainable alternatives to synthetic products.

## 4. Methodology

This research was carried out due to the growing public interest in bio-based products [43] and the realisation that there was little reliable literature reporting the knowledge and attitudes toward the use of materials such as plastics and rubbers and their effects on the environment [39]. The vast production and usage of rubbers, as well as the fate of their waste, offer a grim image of the motor-vehicle tyre ecosystem in Malaysia, which has also fuelled our interest in bio-based products [44].

An online survey was developed and distributed to the general public in order to identify perceived opportunities, strengths, and challenges for the use of bio-based materials and to contribute to the achievement of a suite of SDGs, particularly SDG 12 (Responsible Consumption and Production). The questionnaire, which includes questions relating to general environmental concern, waste production and recycling behaviour, was developed based on a variety of periodical environmental surveys, including the Organisation for Economic Co-Operation and Development (OECD) survey on general environmental concern, waste production, and recycling behaviour [45] and a European waste survey about plastics, personal health, and the role of multiple parties (individuals, governments, and businesses) in addressing environmental issues [46]. The online survey was carried out between the 10 August 2021 and the 31 January 2022, with the questionnaire circulated via appropriate emails (such as the University of Malaya's researchers' and students' networks) and online media platforms (such as Facebook and Reddit). Our survey used a combination of multiple-choice and Likert scale, similar to other large-scale studies for the same purpose [47,48]. The survey was refined by five field experts and piloted with a random sample of members of the general public with varying levels of knowledge. The final version was submitted to the University Malaya Research Ethics Committee (UMREC) for ethical approval.

After the ethics application was granted in September 2021, formal data collecting commenced, and 316 replies were received. Data filtering was undertaken to exclude any respondents who answered the survey twice or offered incoherent answers for the open-ended responses in order to assure data quality [49]. After data cleaning, 300 data points remained for the final analysis. Figure 2 shows the demographic details of the respondents, including generational cohorts, gender, and the highest level of education. The majority of respondents (n = 210) are females in the Gen Z age group (ages 18 to 25 in 2022). In terms of educational level, 66% of respondents (n = 198) hold a Bachelor's degree, while 24% (n = 72) have completed either a Master's degree (n = 60) or Ph.D. (n = 12). While this survey involved more female respondents with a Bachelor's degree, which may not be representative of a general population, the demographic distributions in this study are consistent with the survey response patterns reported by Smith [50], who found that females are more likely than males to participate in online surveys, younger generations are more likely to participate than older generations, and more affluent and educated people are more likely to participate than less affluent and less educated people.

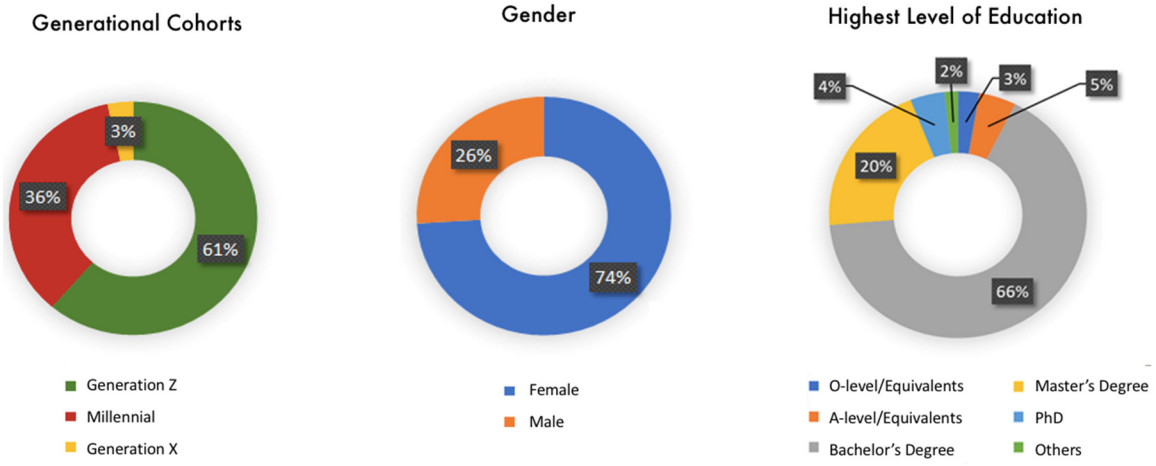



**Figure 2.** Demographic information.

All survey data were interpreted and subjected to descriptive statistics under several categories that represent dimensions of social capital (or cohesion) and sustainability through the use of biodegradable materials, particularly oxo-biodegradable rubber. Chi-squared tests for independence were performed to determine whether there were significant differences between tested variables (cut-off of $p = 0.01$). The Mann-Whitney test was employed to compare gender categories, while the Kruskal-Wallis test was employed to compare generational cohort and highest education level. For variables where the Kruskal-Wallis test revealed significant differences between groups, the Mann-Whitney test with a Bonferroni correction was used to confirm the results. Pearson's correlation was also carried out to assess the strength of the relationship between the two variables. The statistical inference was performed using IBM software SPSS Statistics 28.0.

## 5. Results

### *5.1. Public Knowledge and Attitudes towards Consumption of Bio-Based Products*

According to recent studies, the term "bio-based" products is often misunderstood, leading to the misconception that all bio-based products, such as bio-based plastics, are biodegradable [26,51]; this is evident in the analysis of one of our survey questions, which asked respondents if they thought all bio-based goods are biodegradable (Figure 3). Misconception and confusion can pose a number of challenges to the waste management industry. For example, bio-based plastic packaging waste can end up in organic waste streams and contaminate them, undermining efforts to reduce littering and plastic pollution. Hence, it is critical to increase public awareness and understanding of bio-based products. On a positive note, despite their lack of knowledge about bio-based materials, more than half (57%) of the respondents are willing to spend extra to help the environment. Figure 4 shows that only 12% of respondents (n = 36) either disagree or strongly disagree with paying up to 10% more for bio-based materials in order to reduce environmental damage.

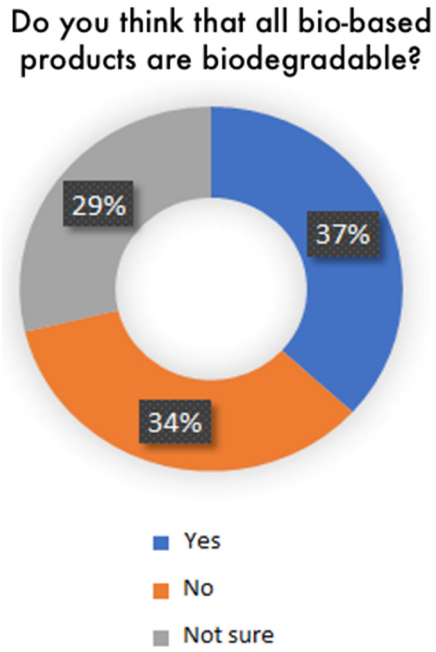



**Figure 3.** Understanding of bio-based materials.

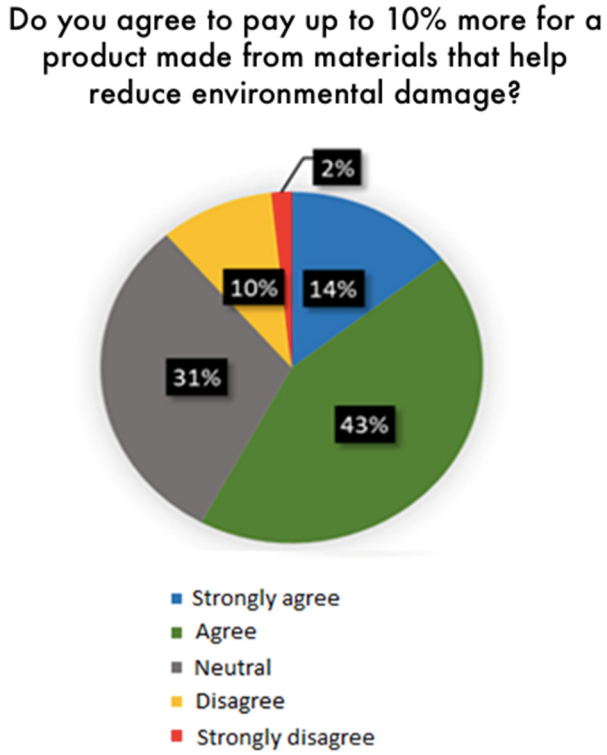



**Figure 4.** Willingness to pay extra for sustainable materials.

### *5.2. Public Perceptions and Awareness of the Environmental Impact of High Synthetic Rubber Utilization and Poor Waste Management*

A 5-point Likert scale was used to assess respondents' awareness of the effects of high rubber utilisation and pollution on the environment (Figure 5). The majority of respondents perceived excessive utilisation of synthetic rubber as a serious issue, with more than 80% agreeing or strongly agreeing that measures should be taken to reduce the amount of synthetic rubber used (Figure 5). Furthermore, more than 80% of respondents agreed or strongly agreed to minimise their use of conventional rubber products in favour of

bio-based alternatives (Figure 5); this could be because they are aware that their choices can benefit the environment. These findings are consistent with a recent study conducted in Ireland and the Netherlands by Gaffey et al. [43], which found that a larger majority of consumers would prefer to buy bio-based products over fossil-based products. According to our correlation analysis, the ability to control the amount of rubber products used has no relationship with the readiness to reduce or replace synthetic rubber consumption.

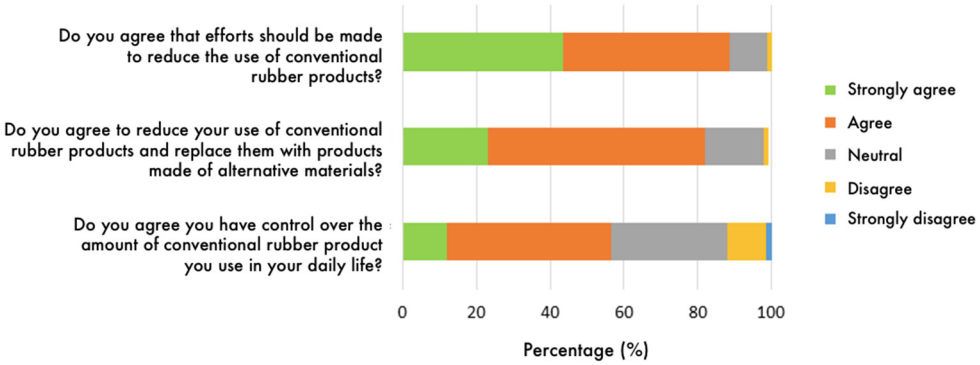



**Figure 5.** Perceptions of environmental issues associated with synthetic rubber.

Although a majority of respondents were well aware of the issues posed by synthetic rubber and willing to use products made from alternative materials, only 33% (n = 99) had heard of oxo-biodegradable rubber (Figure 6), irrespective of their age (n = 300; $\chi^2 = 4.633$; $p = 0.099$) and education (n = 300; $\chi^2 = 9.253$; $p = 0.055$); this could be due to the fact that oxo-biodegradable products are still relatively new on the market [36,52]. Nonetheless, 70% (n = 69) of the 99 respondents who had heard of oxo-biodegradable thought it was a good material that would help reduce rubber pollution (Figure 6). Figure 7 depicts respondents' perceptions and concerns about the environmental issues caused by synthetic and oxo-biodegradable rubbers. Generally, most respondents thought that the widespread use of conventional rubber products was not sustainable in the long run, and that products made of oxo-biodegradable rubber were more sustainable and a better alternative to synthetic rubber. They were concerned, however, if conventional and oxo-biodegradable rubber products ended up in the ocean or landfills (Figure 7), though they thought the latter posed less of a threat. The findings are consistent with recent research by Gaffey et al. [43] and Stahl et al. [53], which reported that customers have a favourable outlook on bio-based products and are willing to purchase them, particularly at a reasonable price.

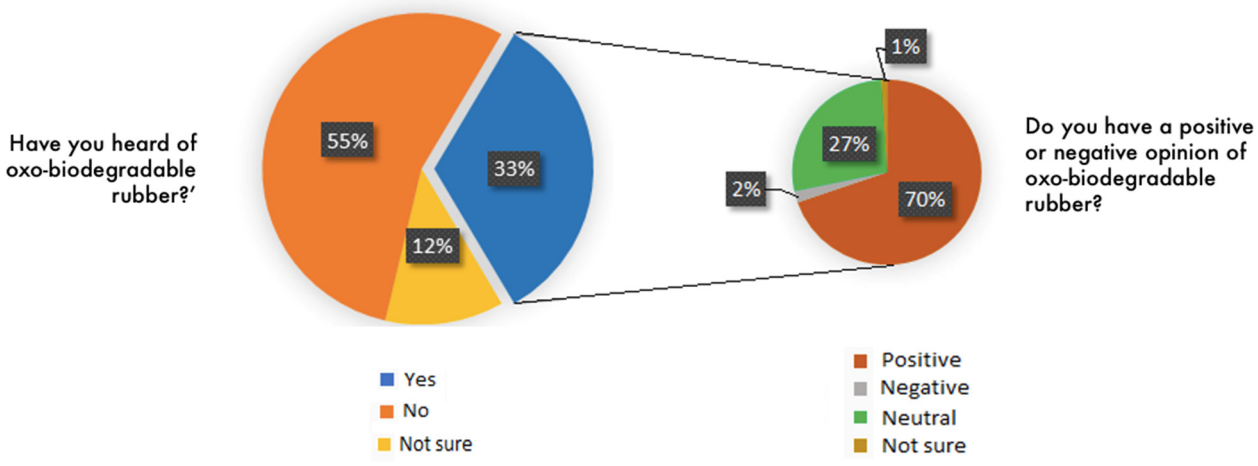



**Figure 6.** Understanding of oxo-biodegradable rubber.

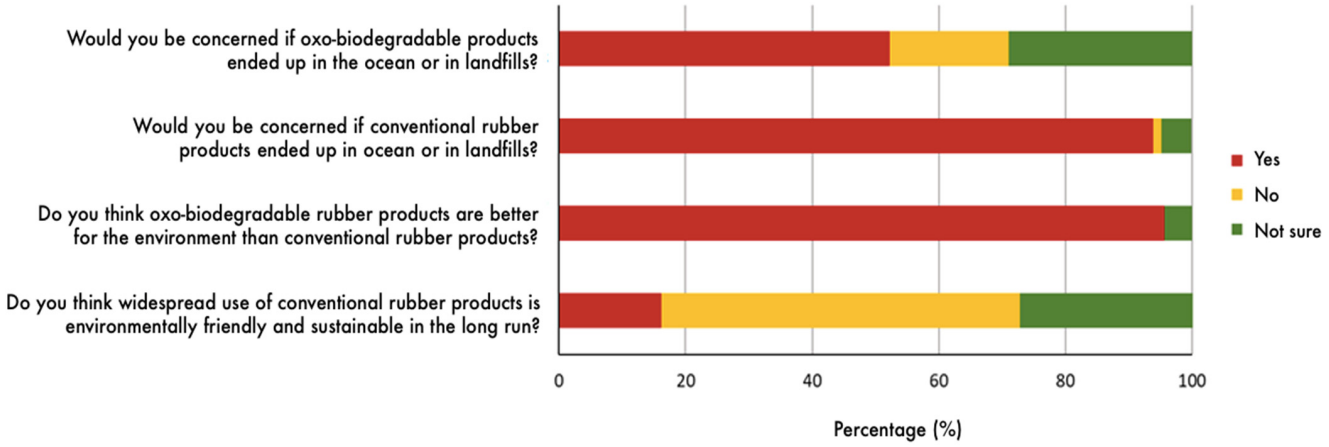



**Figure 7.** Perceptions of environmental issues associated with conventional and oxo-biodegradable rubber products.

In terms of rubber waste management, we found that 58% (n = 174) and 26% (n = 78) of respondents, respectively, either segregate and dispose of rubber waste or only segregate rubber waste (Figure 8). Although more than 80% of respondents segregate their rubber waste, only 21% (n = 63) are extremely concerned about the amount of rubber waste produced per day in their native country, and 71% (n = 213) are somewhat concerned (Figure 8); this indicates that there is still a low level of awareness about the amount of rubber waste produced and its impact on humans.

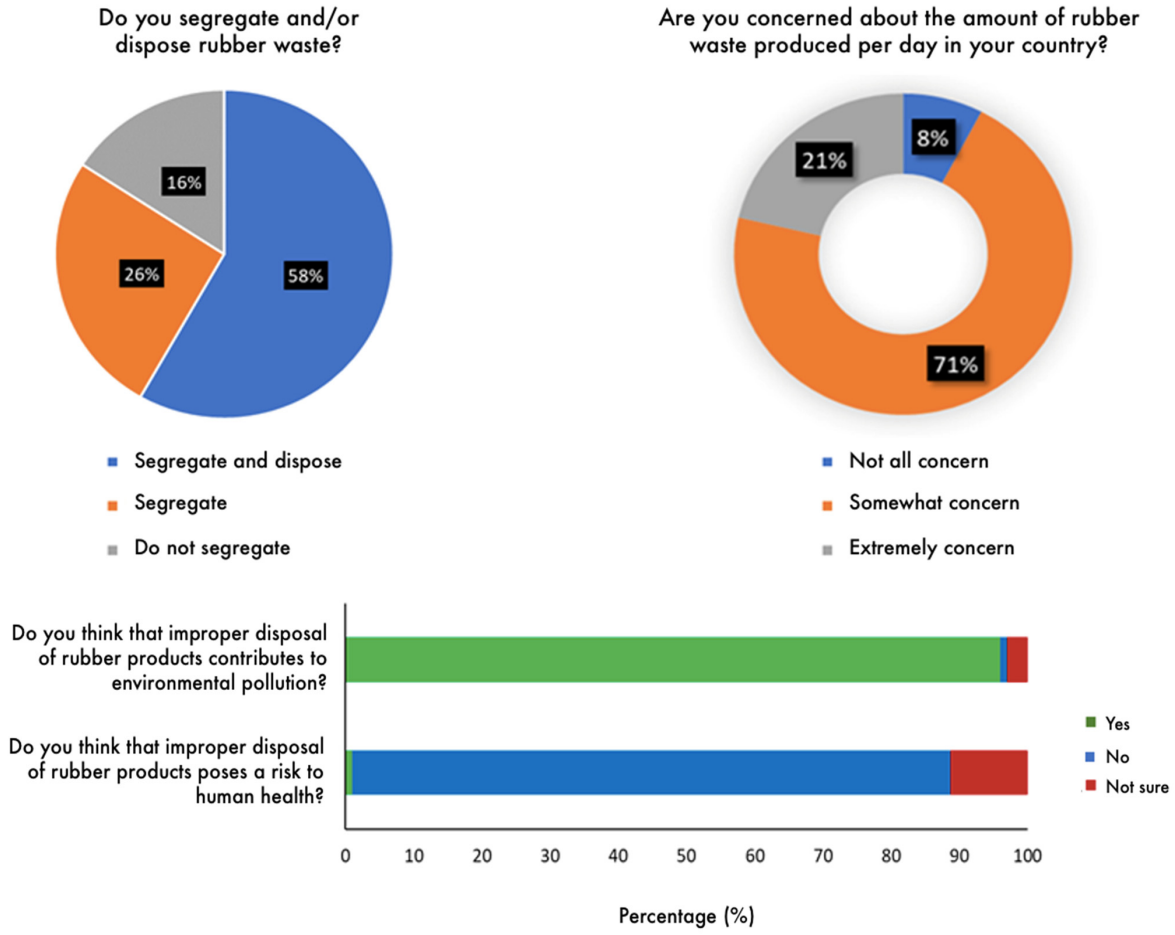



**Figure 8.** Approaches to rubber waste management and perceptions of rubber waste issues.

### *5.3. Efforts to Reduce the Use of Conventional Products*

In order to understand public perceptions of the level of accountability of different actors, respondents were also asked to identify the level of responsibility for reducing the use of conventional products that cause environmental damage. The majority of respondents consider themselves to be "mostly responsible" and "responsible" in reducing their use of conventional products that harm the environment (Figure 9). A similar finding was reported in a survey study on bioplastics [54]; however, respondents in this study believed that the government and industry had larger roles to play, with the latter seen as the most responsible actor in managing the use of conventional products (Figure 9); this could be due to the fact that educational and awareness-raising measures or initiatives are frequently designed by the government or policymakers, whereas industries are the primary producers of conventional products such as rubber tyres and gloves.

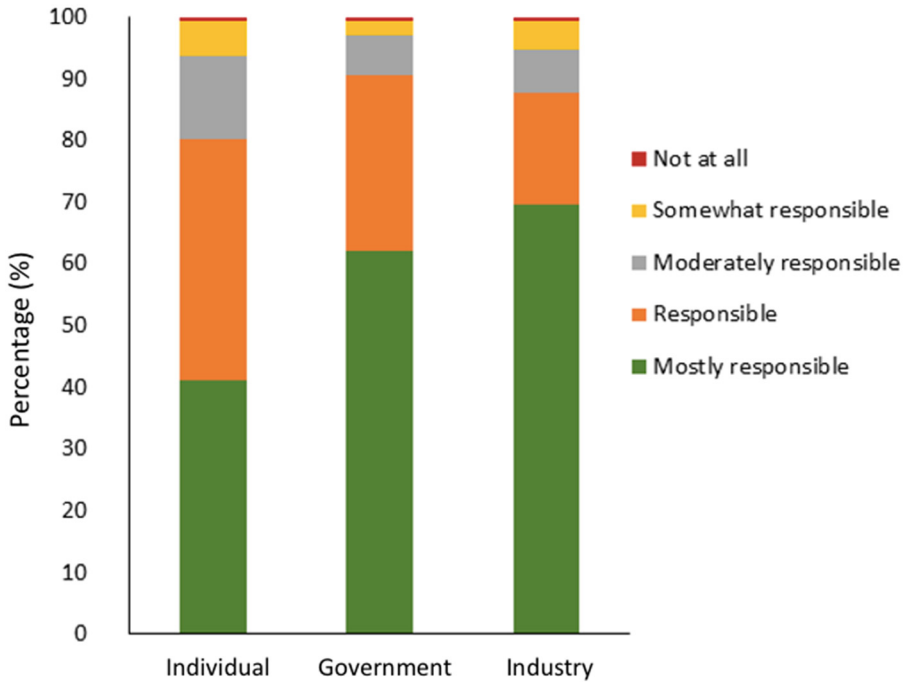



**Figure 9.** Perceptions of the players involved in reducing the use of conventional products.

It is worth noting that some survey respondents expressed a desire for a shift in industry behaviour, as well as a general reduction in the use of conventional products. When considering these responses, it is evident that respondents were aware of the environmental issues posed by synthetic materials, and that the general public demonstrated a positive attitude toward the use of bio-based products; this suggests that bio-based products could be a long-term solution for mitigating the environmental effects of conventional product waste, corroborating the findings of Filho et al. [54] and Van der Oever et al. [55].

## 6. Discussion

There has been a lack of a specific research tool to capture attitudes or perspectives on the impacts of bio-based materials, although anecdotal evidence of greater public awareness of the effects of plastics has been observed in recent years [48]; therefore, the present study sought to ascertain the extent to which the general public understands and uses bio-based products and their awareness of current issues surrounding these products and their waste, as well as to assess perceptions of the use and waste management of bio-based products, particularly oxo-degradable rubbers.

Based on our survey, the majority of respondents had a misunderstanding of what bio-based products are. When asked if they think all bio-based products are biodegradable, the majority of the 300 respondents—irrespective of their age (n = 300; $\chi^2 = 3.257$; $p = 0.196$)

and education (n = 300; $\chi^2$ = 4.617; $p$ = 0.329)—either gave the incorrect answer ("Yes"; 37%) or were unsure about the answer ("Not sure"; 29%) (Figure 3); this demonstrates that consumers often believe that bio-based products are biodegradable, making rapid littering somewhat acceptable to them [26,56]. The study conducted by Stahl et al. [53] and Carus et al. [57] also found that most consumers had little knowledge of concepts such as "bio-based" and "biodegradable". More surprisingly, while more than 90% of respondents thought that improper disposal of rubber products leads to environmental pollution, more than 80% did not think that it would harm human health (Figure 8); this paints a clear picture of the dire need for increased awareness and knowledge among consumers, as suggested by Gaffey et al. [43] and Sabini et al. [58]. The survey on bioplastics conducted by Filho et al., (2021) revealed that consumers have insufficient information about bioplastics and bioproducts in general.

By and large, our survey reveals that respondents are concerned about the potential environmental implications of synthetic rubber or other materials. Despite the fact that there are still misconceptions and confusion about bio-based materials, respondents expressed a willingness to purchase products at a higher or reasonable price (Figures 3 and 4); this corroborates with the study conducted by Al Mamun et al. [59], which reported that eco-literacy and environmental concern have a positive effect on attitudes toward environmentally friendly products among low-income households in Malaysia. As such, more efforts should be made to improve public understanding of bio-based and biodegradable concepts, and that more research should be conducted to provide more sustainable alternatives to synthetic materials (Figure 10). Additionally, the majority of respondents showed an interest in reducing the use of conventional rubber products and replacing them with sustainable alternatives such as oxo-biodegradable rubber (Figures 6 and 7). These findings highlight the importance of additional research to develop sustainable alternatives to rubber, similar to the study on bio-based products or plastics conducted by Gaffey et al. [43] and Filho et al. [54].

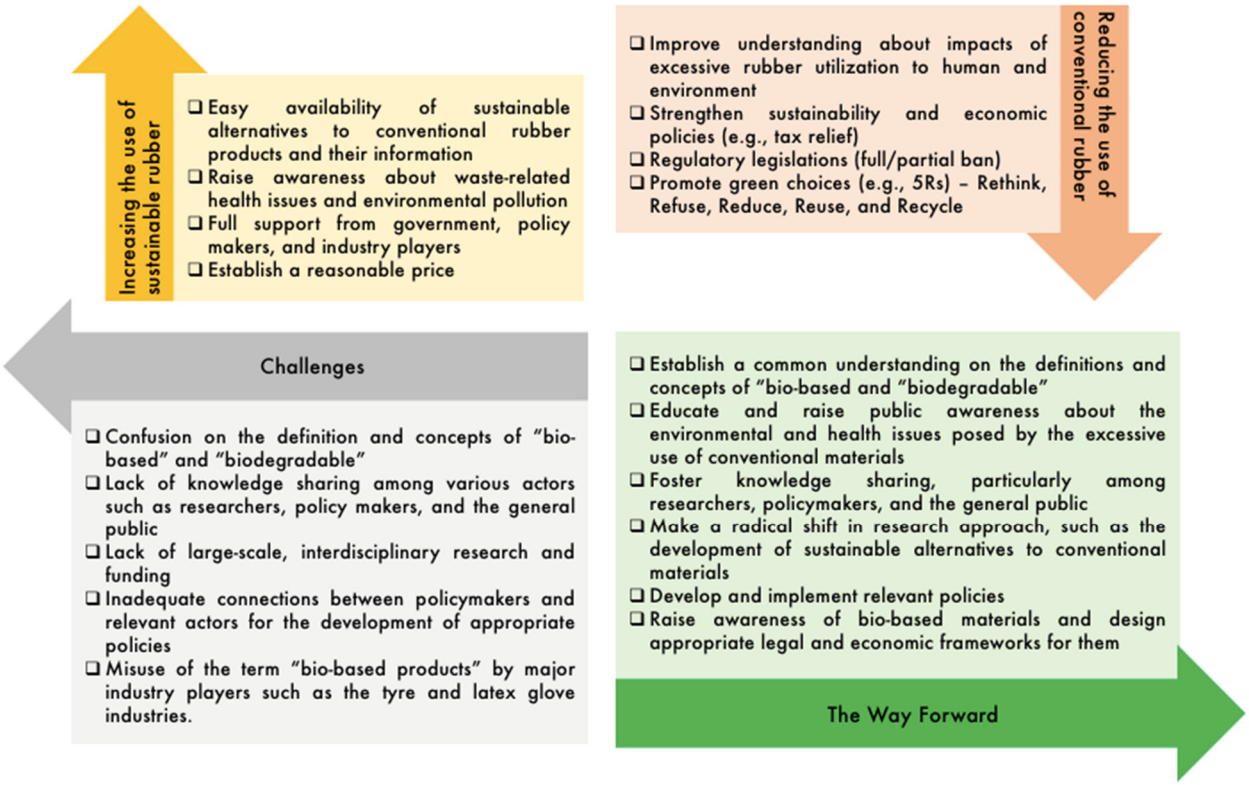



**Figure 10.** Illustration of the survey's conclusions to increase the use of sustainable rubber and reduce the use of synthetic rubber, as well as the challenges that these efforts face and the way forward.

Figure 10 illustrates the potential measures or efforts that could be used to increase the use of sustainable rubber while reducing the use of synthetic rubber based on the overall survey results and additional comments from the public. In general, public understanding and awareness of bio-based materials should be improved, which could be accomplished with the assistance of researchers to spread awareness and develop more sustainable and affordable alternative rubber materials. Statistical inferences revealed an insignificant association ($p > 0.05$) between gender, generational cohorts, and the highest level of education on public knowledge and awareness, implying that broad public awareness initiatives or campaigns should be conducted regardless of age and educational background. Additionally, relevant policies should be developed and strengthened by multiple players, particularly government and policymakers, and green or sustainable choices should also be widely promoted [43,60].

Although bio-based materials are gaining popularity in many countries, there are still a number of challenges to overcome before bio-based rubber is widely accepted, and there are steps that can be taken to address these challenges (Figure 10). For example, it is vital to establish consistent definitions and a common understanding of terms such as "bio-based" and "biodegradable" [23]; this will avoid public misconceptions and the irresponsible industry players from misusing or exploiting the terms for personal gains. Every actor, including researchers, policymakers, regulators, industrial players, and the general public, play critical roles in building a more sustainable future using bio-based materials (Figure 10). We believe that effective knowledge sharing about bio-based materials and products, as well as impactful research, appropriate policies, legislation, and regulations, can help to achieve a more sustainable future in the face of climate change.

## 7. Conclusions

Based on the survey's overall finding, the majority of respondents lacked understanding of terms such as "bio-based" and "oxo-biodegradable", but they were aware of the environmental issues associated with the use of products made from synthetic or non-sustainable materials and were interested to be engaged in reducing their use of these products and adopting sustainable alternatives. Interestingly, the survey discovered that the respondents are willing to spend more for bio-based products; this could be due to respondents' concerns about the potential pollution caused by materials (such as plastics and rubbers) in terrestrial and aquatic environments. Our findings also point to the necessity for educational or awareness efforts that promote bio-based materials and warn consumers about the dangers of using synthetic materials; this, however, can only be accomplished if a variety of actors, including researchers, policymakers, industry players, and the general public, play their parts.

Our survey has a limitation in that the sample cannot be considered representative of the broader population in Malaysia because the majority of respondents have a bachelor's degree; thus, the findings may not be applicable to a larger, less educated population. Our findings, however, are substantial in the sense that they offer unprecedented insights toward public attitudes and perceptions about the utilization of synthetic and bio-based materials, notably bio-based and oxo-biodegradable rubbers. More research is needed to gain a practical grasp of public views and attitudes toward sustainable materials, as well as those of industry players. Engaging the broader public is essential, and enforcing extended industry accountability or responsibility through laws and regulations is especially crucial in mitigating potential environmental damage. In addition, further research is also needed to determine the feasibility and utility of sustainable materials, particularly for environmental benefit.

In conclusion, our research provides a compelling picture of Malaysian citizens' behaviour and views toward the use of conventional and bio-based products. More efforts are required to educate the public about terminology (such as "bio-based" and "oxo-biodegradable") and raise awareness about the consequences of using conventional products excessively; it is also critical to establish more long-term solutions, including develop-

ing more sustainable alternatives. A combination of sound policies or regulations, as well as increased knowledge and awareness, could aid in addressing the underlying challenges, particularly in alleviating the pressures currently imposed on the physical environment.

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