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Advantages and Challenges of Biobased Plastics: A Qualitative Analysis of Stakeholders' Perceptions

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Abstract

The circular economy mostly relies on the reduction of fossil-based materials. Finding economically viable, low-cost, renewable, and biodegradable alternatives to plastic packaging is a significant challenge for this aim since it is widely used in the daily consumption of various products. Bioplastics are already considered promising substitutes for packaging materials since they are biodegradable, use renewable resources, and release fewer greenhouse gases. However, the shift from fossil-based to biobased materials also has its difficulties. This study uses qualitative data collected from three primary stakeholder groups of this transition, namely, R&D managers from the packaging industry, researchers, and policymakers. The research findings show that stakeholders are mostly in consensus regarding the advantages and challenges of the shift from fossil-based plastic to bioplastics. The knowledge and awareness of the process are highly compatible with the literature on the subject. Additionally, the findings suggest that

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although bioplastics have the potential to contribute significantly to sustainability goals and the circular economy greatly costs, lack of regulations, incentives and inadequate recycling infrastructure are major obstacles to change. The agreement of stakeholders on the matter of challenges also reveals the need for common ground for a solution.

Keywords: Bioplastics, sustainability, circular economy, renewable resources, biodegradable materials.

Biyobazlı Plastiklerin Avantajları ve Zorlukları: Paydaşların Algıları Üzerine Nitel Bir Analiz

Öz

Döngüsel ekonomi büyük oranda fossil-bazlı malzemelerin azaltılmasına dayanmaktadır. Bu amaca ulamada plasitk ambalajlara ekonomik olarak uygulanabilir, düşük maliyetli, yenilenebilir ve biyolojik olarak parçalanabilir alternatifler bulmak önemli bi güçlüktür çünkü plastic ambalajlar birçok ürünün gündelik tüketiminde yaygın olarak kullanılmaktadır. Biyoplastikler biyolojik olarak parçalanabilir olduklarından, yenilenebilir kaynaklar kullandıklarından ve daha az sera gazı salınımına neden olduklarından dolayı halizaırda ambalaj malzemesi olarak umut vaadetmektedirler. Ancak fosil- bazlıdan biyolojik bazlı malzemelre geçişin kendi zorlukları bulunmaktadır.

Bu çalışma söz konusu geçişin üç önemli paydaşı olan ar-ge yöneticileri, araştırmacılar ve politika yapıcılardan toplanan nitel veriyi kullanmaktadır. Araştırma bulguları paydaşların fosil- bazlı plastikten biyolojik bazlı plastiğe geçişin avantajları ve zorlukları konusunda büyük oranda hemfikir olduklarını göstermektedir. Süreçle ilgili bilgi ve farkındalık düzeyleri yüksek ve konuyla ilgili litratürle uyumludur. Ek olarak bulgulardan biyoplastiklerin sürdürülebşilirlik hedeflerine ve döngüsel ekonomiye büyük katkı sağlama potansiyeli olduğu halde maliyetler, regülasyonların ve teşviklerin olmayışı ile yetersiz geridönüşüm alt yapısının değişimin önündeki büyük engeller olduğu anlaşılmaktadır. Paydaşların zorluklara ilişkin argümanları ise çözüm için ortak bir zemine ihtiyaç olduğunu ortaya çıkartmıştır.

Anahtar Kelimeler: Biyoplastikler, sürdürülebilirlik, döngüsel ekonomi, yenilenebilir kaynaklar, biyolojik olarak parçalanabilir malzemeler.

Introduction

Most of the driving forces behind the circular economy aim at the reduction of to reduce ageing[1]. Plastic packaging has brought convenience and benefits to our daily lives since it plays a vital role in providing, protecting, and delivering high-quality products to consumers worldwide in almost every market segment. The production of plastic packaging has increased significantly in recent years and has become the largest polymer application, constituting 26% of the total volume. Plastics have replaced other packaging materials because they are lightweight and have good barrier qualities, and their production is expected to double in the next 20 years[2]. However, the production of fossil-based plastic packaging significantly increases greenhouse gas emissions. Furthermore, the failure to adequately control the flow of fossil-based plastic waste increasingly pollutes the oceans and land irrigation networks daily, making it an urgent international problem[3]. Therefore, to mitigate the environmental repercussions of fossil-based plastics and ensure a more circular plastic economy, solutions should be developed to reduce plastic packaging garbage and provide more effective waste management[4]

In this context, the development of economically viable, low-cost, renewable, and biodegradable alternatives such as biobased plastics is of great interest to satisfy the ever-growing demand for plastics and control the resulting waste stream[5] These materials possess the potential to substitute numerous high-volume commercial products reliant on fossil-based plastics and are progressively being employed across various sectors, including packaging, consumer electronics, food and beverage items, automotive, agriculture, and toys. In particular, packaging

1 Nicole M. Stark - Laurent M. Matuana, "Trends in Sustainable Biobased Packaging Materials: A Mini Review", *Materials Today Sustainability,* 15, November 2021, 100084, https://doi.org/10.1016/j.mtsust.2021.100084.

2 World Economic Forum, "The New Plastics Economy Rethinking the Future of Plastics", 2016.

3 H. N. Salwa - S.M. Sapuan - M.T. Mastura - M.Y.M. Zuhri, "Green Bio Composites for Food Packaging", *International Journal of Recent Technology and Engineering* 8, no. 2, Special Issue 4, July 2019, 450–59; https://doi.org/10.35940/ijrte.B1088.0782S419.\\uc0\\u8221{}{\\i{}International Journal of Recent Technology and Engineering} 8, no. 2 Special Issue 4 (July 2019

4 Diogo A. Ferreira - Filipe et al., "Are Biobased Plastics Green Alternatives?—A Critical Review", *International Journal of Environmental Research and Public Health,* vol.18, no. 15, July 2021, 7729; https://doi.org/10.3390/ijerph18157729.

5 Kai Chi - Hui Wang - Jeffrey M. Catchmark, "Sustainable Starch-Based Barrier Coatings for Packaging Applications", *Food Hydrocolloids,* 103, June 2020, 105696; https://doi.org/10.1016/j.foodhyd.2020.105696.

represents the most prominent application area for biobased plastics, constituting 48% of the biobased plastic market (1.15 million tons) in 2021[6]. This amount is still relatively small compared to the global production of oil-based plastic packaging (280 million tons). Still, it offers the potential for significant change if the industry focuses on accepting these new materials[7].

To qualify as a bioplastic, a plastic material should be derived either partially or entirely from organic sources, such as grains, starchy root vegetables, sugarcane, or vegetable oils. Alternatively, it can encompass plastics capable of dissolution in water, carbon dioxide, and methane, along with inorganic substances that naturally decompose with specific environmental conditions and microbial action[8]. Biobased plastics can be made from various renewable resources (e.g., plant, algae, and residue-based), and according to cradle-to-grave life-cycle evaluations, they have certain advantages compared to their fossil-based contenders/equivalents. For example, compared to polyethene terephthalate, one of the most frequently used fossil-based plastics, the production of equivalent biobased polyethene furoate provides a 40% reduction in fossil resources and a 40-50% reduction in greenhouse gases[9][10]. Many biobased plastics offer improved

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6 European Bioplastics, “Bioplastics Facts and Figures”, 2022.

7 Ibid.

8 Sarah Kakadellis - Jeremy Woods - Zoe M. Harris, “Friend or Foe: Stakeholder Attitudes towards Biodegradable Plastic Packaging in Food Waste Anaerobic Digestion”, *Resources, Conservation and Recycling*, 169, June 2021, 105529; https://doi.org/10.1016/j.resconrec.2021.105529.

9 Rajni Hatti-Kaul - Lars J Nilsson - Baozhong Zhang - Nicola Rehnberg - Stefan Lundmark, “Designing Biobased Recyclable Polymers for Plastics”, *Trends in Biotechnology* 38, no. 1, January 2020, 50–67; https://doi.org/10.1016/J.TIBTECH.2019.04.011.but also a rational design of the polymers with both desired material properties for functionality and features facilitating their recyclability. Biotechnology has an important role in producing polymer building blocks from renewable feedstocks, and also shows potential for recycling of polymers. Here, we present strategies for improving the performance and recyclability of the polymers, for enhancing degradability to monomers, and for improving chemical recyclability by designing polymers with different chemical functionalities.</p>”,”container-title”:”Trends in Biotechnology”,”DOI”:”10.1016/J.TIBTECH.2019.04.011”,”ISSN”:”0167-7799”,”issue”:”1”,”note”:”publisher: Elsevier\nPMID: 31151764”,”page”:”50-67”,”title”:”Designing Biobased Recyclable Polymers for Plastics”,”volume”:”38”,”author”:[{“family”:”Hatti-Kaul”,”given”:”Rajni”},{“family”:”Nilsson”,”given”:”Lars J.”},{“family”:”Zhang”,”given”:”Baozhong”},{“family”:”Rehnberg”,”given”:”Nicola”},{“family”:”Lundmark”,”given”:”Stefan”}],”issued”:{“date-parts”:[[“2020”,1]]}}}],”schema”:”https://github.com/citation-style-language/schema/raw/master/csl-citation.json”}

10 Hajime Nakajima - Peter Dijkstra - Katja Loos, “The Recent Developments in Biobased

new material properties, including improved breathability, increased material resistance, reduced thickness, and enhanced optical properties. Innovative materials such as PLA (polylactic acid), PHA (polyhydroxyalkanoate), or biobased bio-PBS (polybutylene succinate) provide additional end-of-life solutions, as they are biodegradable in certain environments. Other new materials, such as 100% biobased PEF, have better barrier properties than comparable conventional polymers and can be easily recycled mechanically[11]

The production capacity of biobased plastics, recognized for their potential in promoting circular economy principles, was estimated at approximately 2.42 million tons in 2021, with projections indicating a rise to approximately 7.59 million tons by 2026[12]. Despite these advancements, biobased plastics constitute only 1% of the global plastics market but are anticipated to increase to 2% by 2026[13]. On the other hand, the global bioplastic packaging market is estimated to reach approximately USD 7 billion in 2021, growing 2.4 times and achieving a CAGR of 14% by the end of this decade[14]. These developments are expected to impact the biobased plastics industry significantly, increasing the popularity and demand for biobased plastics used in packaging.

However, whether biobased plastics can replace fossil-based plastic packaging remains unanswered. The literature is insufficient to provide a definitive answer to this question. Therefore, a comprehensive research approach is needed to address this issue. The current research aims to examine the advantages and challenges of biobased plastic packaging compared to fossil-based plastic packaging in the transition to a circular economy. Participants selected from different stakeholder groups (industry representatives, academics, government officials, and civil society experts) contribute to a broad understanding by bringing together diverse viewpoints.

Polymers toward General and Engineering Applications: Polymers That Are Upgraded from Biodegradable Polymers, Analogous to Petroleum-Derived Polymers, and Newly Developed", *Polymers* (MDPI AG), October 2017; https://doi.org/10.3390/polym9100523.

11 Bioplastics, "Bioplastics Facts and Figures".

12 Ibid.

13 Ibid.

14 "Global Market Study on Bioplastics Packaging: Bans on Single-Use Plastic to Bode Well for Market Growth", n.d.; https://www.persistencemarketresearch.com/market-research/bioplastic-packaging-market.asp.

Methods

Research Design

The research methodology adopted is grounded theory, which represents a qualitative research approach tailored to systematically collect and analyze data, facilitating the construction of a theoretical model[15]. Given the study's objective to discern the benefits and obstacles of biobased plastic packaging, the grounded theory approach was explicitly selected for this research.

The preliminary stage of the study involved a literature review before data collection[16]. The literature review encompassed theories, frameworks, and previous studies relevant to the advantages and challenges of biobased plastic packaging.

The data utilized in this study consists of transcriptions obtained from semi-structured interviews and corroborating documentary evidence. The aim is to create an explanatory framework encapsulating the participants' perspectives. Comprehensive data were collected from 13 participants in the purposeful sample. Following data collection, codes were developed, leading to the delineation of categories and themes. Throughout both data collection and analysis, detailed field notes were taken.

Overall, the grounded theory approach, complemented by an extensive literature review and rigorous data analysis, aimed to provide a comprehensive understanding of the advantages and challenges of biobased plastic packaging.

Participants

In this study, semi-structured interviews were conducted with 13 participants. The selection of participants was carefully made to achieve the study's objectives and provide answers to the research questions, aiming for diversity in terms of sectors and areas of expertise (see Table 1). Three participants were research and development managers from companies involved in the production of plastic packaging in Turkey. Five participants were scholars researching biobased plastics. Two participants were experts working in the UN Environment Program. Additionally, two participants were experts who participated in the Workshop Report on Flexible Food-Grade Plastic Packaging published by the OECD in 2023. Finally, one of the participants was involved in the "The New Plastics Economy: Rethinking the Future of Plastics" study published by the World Economic Forum in 2016.

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15 Juliet Corbin - Anselm Strauss, *Basic of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, third, Sage Publications, 2008.

16 Ibid.

This diverse group of participants aims to broaden the scope of the study and evaluate the advantages and challenges of biobased plastic packaging from various perspectives.

Table 1. Participants

Interviewee	Institution	Years of Experience	Location	Gender	Age
R&D Manager 1	Sarten Packaging Company	6	Turkey	Male	41
R&D Manager 2	Netpak Packaging	5	Turkey	Male	38
R&D Manager 3	Lidersan Packaging	8	Turkey	Male	53
Scholar 1	Koc University	15	Turkey	Female	49
Scholar 2	Weber State University	11	USA	Female	39
Scholar 3	Hamburg University of Technology	35	Germany	Male	64
Scholar 4	Rochester Institute of Technology	18	USA	Female	48
Scholar 5	University of Bern	13	Switzerland	Male	56
Expert 1	Biotec	6	Thailand	Male	33
Expert 2	UN Environment Program	10	Kenya	Male	36
Expert 3	UN Environment Program	21	Kenya	Female	51
Expert 4	Ellen MacArthur Foundation	14	UK	Female	42
Expert 5	NatureWorks	32	USA	Male	61

Data Gathering Procedure

An e-mail was sent to each participant via the official e-mail address of the General Directorate of R&D Incentives, with the permission of the Turkish Ministry of Science and Technology. The email conveyed the objectives and scope of the research to each participant, extending an invitation to participate in the study. The chosen data collection modes were face-to-face, telephonic, or conducted through ZOOM interviews. The study used two primary forms of data collection: first, semi-structured interview sessions incorporating open-ended questions, and second, memos generated and documented throughout the research progression.

The interviews were conducted in Turkish and English. The researcher then translated the Turkish data into English and transcribed it. The interviews were held between 15th April and 15th May 2023 and were scheduled for one hour each.

After some general conversation regarding biobased plastic packaging, four questions were asked in the first round of interview sessions. The questions are as follows:

Are biobased plastic packaging part of a circular economy?

How do you characterize biobased plastic packaging?

Could biobased plastic packaging replace fossil-based plastic packaging in the future?

What do you think of using biobased plastic materials in packaging production?

What are the advantages and challenges of using biobased plastic raw materials?

Data Analysis

The data analysis process followed the principles of grounded theory methodology. All interviews were recorded, transcribed verbatim, and coded for themes in the first data analysis stage. First, the transcripts were grouped into common theme categories (open coding). The open coding was repeated in each interview, and each transcript was reviewed. The open coding process ended after four rounds when existing codes covered all relevant parts of the transcripts. As a result, a total of 23 categories were compiled. The axial coding procedure and constant comparison with selective coding were used to establish global classification concepts. According to Boeije (2010), axial coding aims to retain dominant categories and reduce and reorganize data[17]. To determine which categories were dominant, the frequency and consistency of the interview excerpts were initially assessed by reviewing them. Similar factors were merged to develop the final code, which was then grouped into eight final category labels, i.e., in vivo codes. Three category labels focused on biobased plastics' advantages, and five categories focused on their challenges.

Findings

The data analysis revealed definitive findings regarding the advantages and challenges of biobased plastics and their use in packaging to promote sustainability.

Advantages of biobased plastic packaging

1. Lower carbon footprint

Most of those we interviewed emphasized that biobased plastics cause less carbon emissions than fossil-based plastics.

R&D Manager 1: "*Biobased plastics offer a substantially reduced carbon footprint compared to conventional plastics, and it is crucial to account for the carbon dioxide absorption by the plants used in their production, which represents an environmentally beneficial aspect.*"

R&D Manager 2: "*Conventional plastics cause twice the carbon emissions of biobased plastics. I also think the amount of carbon dioxide absorbed by plants used in biobased plastic production during the growing process should be considered when evaluating this issue. In other words, plants, the raw materials of biobased plastics, benefit the environment when grown.*"

Scholar 2: *"Biobased plastics demonstrate a significantly reduced carbon footprint compared to traditional plastics, offering a more environmentally sustainable packaging solution."*

Scholar 4: "*The literature underscores that biobased plastic packaging, exemplified by polylactic acid (PLA), enjoys a notable advantage in terms of a reduced carbon footprint, attributed to lower energy consumption and decreased greenhouse gas emissions during biodegradation, highlighting its environmental benefits.*"

Expert 5: *"Biobased plastics have a significantly lower carbon footprint compared to conventional plastics, and the carbon dioxide absorption by*

17 Hennie R. Boeije, *Analysis in Qualitative Research*, Sage Publications, 2010.

the plants used in their production is an important environmental benefit to consider."

The literature supports the claim that having a lower carbon footprint is a key advantage of biobased plastic packaging. Biobased plastics can exhibit a reduced carbon footprint in comparison to fossil-based plastics[18]. For example, PLA production uses 50% less energy than traditional plastic production[19]. Moreover, PLA releases 70% less greenhouse gases when decomposing in landfills. Furthermore, it has also been proven that the amount of carbon dioxide released during the biological degradation of bioplastics is equal to the amount of carbon dioxide absorbed by the plants from which they are produced[20].

Advantageous material properties

The interviews revealed the versatile advantages of biobased packaging materials, showcasing their substantial support for the circular economy through their renewability, biodegradability, and efficient, clean, and recyclable properties.

R&D Manager 1, "*Biobased plastics have a unique chemical functionality that can improve the performance properties of the resulting packaging. Biobased packaging materials support the circular economy with their efficient, effective, clean, and recyclable properties. It also successfully encloses and shields products, the most important packaging features*."

Expert 1: *"Biobased packaging materials offer circular economy support through their efficient, clean, and recyclable material properties."*

Expert 4: *"Biobased packaging materials, with their unique chemical functionality and advantageous properties such as renewability, biodegradability, and thermal enhancements through additives, support the circular economy, offering efficient, clean, and recyclable features for a variety of applications, effectively enclosing and shielding products."*

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18 Jan Georg Rosenboom - Robert Langer - Giovanni Traverso, "Bioplastics for a Circular Economy", *Nature Reviews Materials* (Nature Research), February 2022; https://doi.org/10.1038/s41578-021-00407-8.

19 "Bioplastics and Biodegradable Plastics - How Do They Work?", n.d.; https://www.explainthatstuff.com/bioplastics.html.

20 Ibrahim Muhammad Shamsuddin - Ahmad Jafar Jafar - Abubakar Sadiq Abdulrahman Shawai - Saleh Yusuf- Mahmud Lateefah - Mahmud Lateefah, "Bioplastics as Better Alternative to Petroplastics and Their Role in National Sustainability: A Review", *Advances in Bioscience and Bioengineering,* vol. 5, no. 4, 2017, 63; https://doi.org/10.11648/j.abb.20170504.13.

Scholar 4: "*Multiple scholarly inquiries have investigated the traits of biobased packaging materials, uncovering advancements in water vapour, mechanical, and thermal permeability characteristics by employing diverse additives and modifications."*

Scholar 5: *"Biobased packaging materials are environmentally friendly and versatile, with advantageous properties such as renewability, biodegradability, gas permeability, transparency, and UV resistance, suitable for various applications including food packaging and building skins."*

Biobased packaging materials are a promising solution to support the circular economy due to their efficient, effective, clean, and recyclable features[21]. Mestre and Cooper (2017) proposed that employing various circular methodologies focusing on different stages of life cycle design can offer practical guidance during the design phase, thereby fostering sustainable design solutions aligned with the Sustainable Development Goals within the circular economy framework[22].

2. Biodegradation as an EOL scenario

The interviewees agree on the advantages of biodegradable biobased plastics, highlighting their environmental benefits, waste reduction capabilities, and contributions to a sustainable circular economy.

R&D Manager 2: "*Biodegradable biobased plastics can undergo natural breakdown by microorganisms into environmentally friendly compounds such as carbon dioxide and water, reducing plastic waste accumulation, minimizing harm to ecosystems, and decreasing the need for long-term waste management.*"

Scholar 1: "*Biodegradable biobased plastics offer the advantage of undergoing natural breakdown by microorganisms into environmentally friendly compounds, reducing the accumulation of plastic waste, minimizing the harm to ecosystems, and decreasing the need for long-term waste management."*

Scholar 5: "*Biodegradation enhances the sustainability of biobased plastics, reducing their carbon footprint, offering recycling compatibility, and promoting a circular economy, while variations in biodegradability and specific degradation conditions should be considered."*

21 Zita Markevičiūtė - Visvaldas Varžinskas, "Smart Material Choice: The Importance of Circular Design Strategy Applications for Bio-Based Food Packaging Preproduction and End-of-Life Life Cycle Stages", *Sustainability,* 14, no. 10, May 2022, 6366; https://doi.org/10.3390/su14106366.

22 Ana Mestre - Tim Cooper, "Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy", *The Design Journal,* 20, no. sup1, July 2017, S1620–35; https://doi.org/10.1080/14606925.2017.1352686.

Expert 2: "Biodegradable biobased plastics offer versatile waste management options, including composting for soil enrichment and anaerobic digestion for renewable energy."

Biodegradation offers several advantages for biobased plastics as an end-of-life (EOL) scenario[23]. Biodegradation denotes how microorganisms decompose materials into elemental compounds, such as carbon dioxide, water, and biomass[24]. This process can occur in various environments, including composting facilities, soil, and marine environments[25]. Biodegradable plastics offer the advantage of reducing the accumulation of plastic waste in landfills and the environment[26]. They can be broken down into nontoxic substances, minimizing their impact on ecosystems and reducing the need for long-term waste management[27].

Furthermore, the biodegradability of biobased plastics opens up new waste management options. Biodegradable plastics can be composted with organic waste, providing a valuable source of nutrients for the soil and promoting a circular economy[28].

Challenges of biobased plastic packaging

1. Challenges in Recycling

The interviews brought to light critical challenges surrounding the recycling of biobased plastics, shedding light on current inadequacies in recycling

23 Jan Gearg Rosenboom - Robert Langer- Giovanni Traverso, "Bioplastics for a Circular Economy", *Nature Reviews Materials,*vol.7 no.2, 2022, 117-137; https:// 10.1038/s41578-021-00407-8.

24 Mirko Cucina - Patrizia de Nisi - Fulvia Tambone - Fabrizio Adani, "The Role of Waste Management in Reducing Bioplastics' Leakage into the Environment: A Review", *Bioresource Technology,* vol. 337, October 2021, 125459; https://doi.org/10.1016/j.biortech.2021.125459.

25 Eri Amasawa - Tomoko Yamanishi - Jun Nakatani - Masahiko Hirao - Shunsuke Sato, "Climate Change Implications of Bio-Based and Marine-Biodegradable Plastic: Evidence from Poly (3-Hydroxybutyrate-Co-3-Hydroxyhexanoate)", *Environmental Science & Technology,* vol. 55, no. 5, March 2021, 3380–88; https://doi.org/10.1021/acs.est.0c06612.

26 Halayit Abrha - Jonnathan Cabrera - Yexin Dai - Muhammad Irfan - Abrham Toma - Shipu Jiao - Xianhua Liu, "Bio-Based Plastics Production, Impact and End of Life: A Literature Review and Content Analysis", *Sustainability,* vol. 14, no. 8, April 2022, 4855; https://doi.org/10.3390/su14084855.

27 Layla Filiciotto - Gadi Rothenberg, "Biodegradable Plastics: Standards, Policies, and Impacts", *ChemSusChem*, vol. 14, no. 1, January 2021, 56–72; https://doi.org/10.1002/cssc.202002044.\\uc0\\u8221{} {\\i{}ChemSusChem} 14, no. 1 (January 2021

28 Sarah Kakadellis - Gloria Rosetto, "Achieving a Circular Bioeconomy for Plastics", *Science,* vol. 373, no. 6550, July 2021, 49–50; https://doi.org/10.1126/science.abj3476.

infrastructure and the pressing need for effective separation methods and specialized streams.

Expert 1: "*The infrastructure for recycling biobased materials is still in its infancy.*"

Expert 2: "*Inadequate recycling infrastructure designed for traditional plastics hinders the efficient recycling of biobased plastics, while low overall plastic collection and recycling rates further diminish their circularity and practical end-of-life solutions.*"

Scholar 3: "*Despite the potential recyclability of biobased polymers, a dedicated recycling stream has not yet been established.*"

R&D Manager 1: "*Recycling biobased plastic packaging is hindered by challenges related to the differentiation between bio-sourced and fossil plastics and the potential mixing of incompatible biobased plastics, underscoring the need for careful consideration of recyclability and functionality in polymer design.*"

R&D Manager 3: "*Methods for separating biobased plastics from other plastics are still insufficient.*"

The challenges associated with recycling biobased plastic packaging are multifaceted and require attention to various aspects of the recycling process. A primary challenge lies in the complexity of differentiating between bio-sourced polymers and fossil-based plastics in the recycling process[29]. Additionally, mixing different biobased plastics, such as PLA, with polyethene terephthalate can lead to degradation and low-quality recycled products[30 31 32].

29 Giulia Cappiello - Clizia Aversa - Annalisa Genovesi - Massimiliano Barletta, "Life Cycle Assessment (LCA) of Bio-Based Packaging Solutions for Extended Shelf-Life (ESL) Milk", *Environmental Science and Pollution Research,* vol. 29, no. 13, March 2022, 18617–28; https://doi.org/10.1007/s11356-021-17094-1.

30 Sebastian Brockhaus - Moritz Petersen - Wolfgang Kersten, "A Crossroads for Bioplastics: Exploring Product Developers' Challenges to Move beyond Petroleum-Based Plastics", *Journal of Cleaner Production,* vol. 127, July 2016, 84–95; https://doi.org/10.1016/J.JCLEPRO.2016.04.003.

31 Federica Ruggero - Riccardo Gori - Claudio Lubello, "Methodologies to Assess Biodegradation of Bioplastics during Aerobic Composting and Anaerobic Digestion: A Review", *Waste Management and Research,* 37, no. 10, October 2019, 959–75; https://doi.org/10.1177/0734242X19854127.

32 Fredric Bauer - Tobias D.Nielsen - Lars J. Nilsson - Ellen Palm- Karin Ericsson - Anna Fråne - Jonathan Cullen, "Plastics and Climate Change—Breaking Carbon Lock-Ins through Three Mitigation Pathways", *One Earth*, vol. 5, no. 4, April 2022, 361–76; https://doi.org/10.1016/j.oneear.2022.03.007.

Another challenge is the lack of a suitable infrastructure for recycling biobased plastic packaging[33]. The existing recycling infrastructure is designed primarily for traditional fossil-based plastics and may not be compatible with biobased plastics[34]. Furthermore, the limited availability of collection and recycling facilities leads to a lower degree of circularity and practical end-of-life outcomes for biobased plastic packaging[35].

2. Incomplete identification standards and life cycle assessment guidelines

The interviewees offered valuable insights into the critical challenges surrounding biobased plastics' life cycle assessment (LCA), highlighting the ongoing efforts to address inconsistencies in methodologies and identification standards.

Scholar 5, "*The lack of consistency and standardization in the LCA methodologies for biobased plastics can lead to inconclusive and incomparable results, hindering their adoption and recognition as sustainable alternatives to conventional plastics.*"

Expert 3: "*ISO 14040 and EN 16760 provide LCA frameworks for biobased plastics, but challenges in methodology and comparability are being addressed through harmonization and sector-specific guidelines."*

R&D manager 1: *"The absence of standardized identification methods for biobased plastics can confuse the market, impeding adoption and market growth, while incomplete LCA guidelines may underestimate their environmental benefits, limiting their recognition as sustainable alternatives to conventional plastics."*

International standards exist, such as ISO 14040 for general life cycle assessments (LCAs) and EN 16760 for specific guidelines on bioplastics, to

33 Irena Wojnowska-Baryła - Dorota Kulikowska - Katarzyna Bernat, "Effect of Bio-Based Products on Waste Management", *Sustainability*, 12, no. 5, March 2020, 2088; https://doi.org/10.3390/su12052088.

34 Corina L. Reichert - Elodie Bugnicourt - Maria-Beatrice Coltelli - Patrizia Cinelli - Andrea Lazzeri - Ilaria Canesi - Francesca Braca - Belén Monje Martínez - Rafael Alonso - Lodovico Agostinis - Steven Verstichel - Lasse Six - Steven DeMets -Elena Cantos Gómez - ConstanceI ßbrücker - Ruben Geerinck - David F.Nettleton - Inmaculada Campos – Erik Sauter - Pascal Pieczyk - Markus Schmid, "Bio-Based Packaging: Materials, Modifications, Industrial Applications and Sustainability", *Polymers,* vol. 12, no. 7, July 2020, 1558; https://doi.org/10.3390/polym12071558.

35 Irena Wojnowska-Baryła - Dorota Kulikowska - Katarzyna Bernat, "Effect of Bio-Based Products on Waste Management", *Sustainability,* vol. 12, no. 5, 2020; https://doi.org/10.3390/su12052088.

guide the framework, methodology, limitations, and underlying assumptions used in LCAs[36]. However, the lack of harmonization and standardization in LCA methodologies can hinder the comparability of different studies and limit the ability to assess the environmental performance of biobased plastic packaging accurately[37]. Furthermore, the absence of standardized identification methods for biobased plastics can lead to confusion and inconsistency in the market, making it difficult for consumers and businesses to differentiate between biobased and conventional plastics[38].

Higher Costs

The interviews highlighted the complex landscape of cost-related challenges surrounding biobased plastics' production, recycling, and waste management, shedding light on the factors contributing to their higher costs and the potential pathways to mitigate these economic challenges.

Expert 2: "*Biobased plastics are costlier due to renewable feedstocks, specialized production, limited economies of scale, and recycling challenges, but ongoing technological advances and supportive policies aim to enhance their economic viability.*"

Expert 5: "*The higher costs of biobased plastics packaging compared to fossil-based plastics packaging are due to factors such as expensive renewable feedstocks, specialized manufacturing processes, limited economies of scale, and more complex recycling and waste management requirements*."

R&D manager 3: "Biobased plastics' *recycling and waste management pose increased complexity and costs compared to fossil-based plastics. This is primarily due to the necessity for dedicated facilities, specific disposal conditions, and escalated sorting and processing expenses resulting from the diverse array of biobased plastic variations.*"

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36 Jan Georg Rosenboom - Robert Langer - Giovanni Traverso, "Bioplastics for a Circular Economy", *Nature Reviews Materials* (Nature Research), February 2022; https://doi.org/10.1038/s41578-021-00407-8.

37 Anina Kusch - Johannes Gasde - Carolin Deregowski - Jörg Woidasky - Claus LangKoetz - Tobias Viere, "Sorting and Recycling of Lightweight Packaging in Germany — Climate Impacts and Options for Increasing Circularity Using Tracer-Based-Sorting", *Materials Circular Economy*, vol. 3, no. 1, December 2021, 10; https://doi.org/10.1007/s42824-021-00022-6.\\uc0\\u8221{} {\\i{}Materials Circular Economy} 3, no. 1 (December 2021

38 Jan Georg Rosenboom - Robert Langer - Giovanni Traverso, "Bioplastics for a Circular Economy", *Nature Reviews Materials* (Nature Research), February 2022; https://doi.org/10.1038/s41578-021-00407-8.

Scholar 3: *"Biobased plastics require specialized equipment, complex processes, and smaller production scales, resulting in higher implementation costs and limited economies of scale than traditional plastics."*

Scholar 4: "*Biobased plastic packaging costs can fluctuate based on factors such as the polymer type, production methods, and market conditions, but ongoing research, technological advances, and government incentives have the potential to mitigate these costs.*"

The higher costs of biobased plastic packaging than fossil-based plastic packaging can be attributed to several factors. First, producing biobased plastics often requires using renewable feedstocks, which can be more expensive than fossil resources[39]. The cultivation and processing of these feedstocks, such as crops or biomass, can involve additional land, labour, and energy[40]costs.

Additionally, the manufacturing processes for biobased plastics may require specialized equipment and technologies, which can be more costly to implement than conventional plastic production methods[41]. The extraction and conversion of biobased feedstocks into polymers may involve complex chemical processes, further adding to production costs[42]. Moreover, the scale of production of biobased plastics is often smaller than fossil-based plastics, resulting in limited economies of scale and higher unit costs[43] [44].

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39 Troy A. Hottle - Melissa M. Bilec - Amy E. Landis, "Biopolymer Production and End of Life Comparisons Using Life Cycle Assessment", *Resources, Conservation and Recycling,* vol. 122, July 2017, 295–306; https://doi.org/10.1016/j.resconrec.2017.03.002.

40 Maria V. Zwicker - Cameron Brick - Gert-Jan M. Gruter - Frenk van Harreveld, "(Not) Doing the Right Things for the Wrong Reasons: An Investigation of Consumer Attitudes, Perceptions, and Willingness to Pay for Bio-Based Plastics", *Sustainability,* vol.13, no. 12, June 2021, 6819; https://doi.org/10.3390/su13126819.

41 Megan Roux - Cristiano Varrone, "Assessing the Economic Viability of the Plastic Biorefinery Concept and Its Contribution to a More Circular Plastic Sector", *Polymers,* vol. 13, no. 22, November 2021, 3883; https://doi.org/10.3390/polym13223883.

42 Badr A. Mohamed - Naoko Ellis - Chang Soo Kim - Xiaotao Bi, "Synergistic Effects of Catalyst Mixtures on Biomass Catalytic Pyrolysis", *Frontiers in Bioengineering and Biotechnology*, vol. 8, December 2020; https://doi.org/10.3389/fbioe.2020.615134.

43 Maria V. Zwicker - Cameron Brick - Gert-Jan M. Gruter - Frenk van Harreveld, "(Not) Doing the Right Things for the Wrong Reasons: An Investigation of Consumer Attitudes, Perceptions, and Willingness to Pay for Bio-Based Plastics", *Sustainability,* vol. 13, no. 12, June 2021, 6819; https://doi.org/10.3390/su13126819.

44 Badr A. Mohamed - Naoko Ellis - Chang Soo Kim - Xiaotao Bi, "Synergistic Effects of Catalyst Mixtures on Biomass Catalytic Pyrolysis", *Frontiers in Bioengineering and Biotechnology*, vol. 8, December 2020; https://doi.org/10.3389/fbioe.2020.615134.

Agricultural impacts

The interviewees underscored the need to examine the intricate relationship between agricultural practices, water resources, land use, and chemical inputs, emphasizing the multifaceted environmental considerations integral to the sustainability of biobased plastics.

Scholar 1: "*It is important to consider the potential environmental impacts of agricultural practices when assessing the sustainability of biobased plastic packaging.*"

Scholar 2*: "The production of biobased plastics, reliant on water for crop irrigation and processing, can strain water resources, particularly in regions already facing water scarcity, with potentially adverse effects on ecosystems, agriculture, and communities."*

Expert 3*: "The environmental implications of biobased plastic packaging are multifaceted, with potential benefits in reducing emissions and fossil fuel dependency but also concerns related to feedstock cultivation and pesticide use, emphasizing the need for holistic sustainability assessments and biodegradable material development for long-term sustainability."*

Expert 4: *"The large-scale cultivation of biobased plastics feedstocks, particularly in areas with intensive agricultural practices, raises concerns about soil erosion, which can lead to topsoil loss, nutrient depletion, and reduced soil fertility, exacerbated by practices such as tillage and monocropping and the potential for deforestation and ecosystem conversion."*

R&D Manager 1: *"Production of biobased plastics from food crops can compete with food production, resulting in environmental impacts, increased food prices, and food security concerns, prompting a transition to nonedible crop sources to address these challenges."*

R&D Manager 3: *"Applying synthetic pesticides and fertilizers to grow feedstocks for biobased plastics can pollute water and cause nutrient runoff, leading to environmental and ecological consequences."*

Several potential negative impacts are associated with the agricultural production of feedstocks for biobased plastics.

First, the production of biobased plastics requires significant land, which can lead to competition with food crops and other agricultural activities. Using land to produce feedstock for biobased plastics can result in deforestation, biodiversity loss, and water pollution[45]. Culturing crops for biobased plastics can compete with food production, potentially leading to higher food prices and security concerns[46].

Second, the production of biobased plastics relies on water resources for crop irrigation and processing. Water is essential for growing and cultivating crops used as feedstocks for biobased plastics[47]. Water is also used to process and manufacture biobased plastics, such as in the extraction and purification of biobased polymers[48]. The reliance on water resources for biobased plastic production can affect water availability and sustainability. This can negatively impact local ecosystems, agriculture, and communities dependent on water resources.

Third, using synthetic pesticides and fertilizers to cultivate feedstocks for biobased plastic packaging can adversely affect soil, water, and biodiversity. Pesticides can contaminate water bodies and harm non-targeted organisms, while the excessive use of fertilizers can cause nutrient runoff, which leads to eutrophication[49].

Fourth, large-scale cultivation of biobased plastic feedstocks can potentially increase the risk of soil erosion. Intensive agricultural practices, such as tillage and monocropping, can exacerbate soil erosion by leaving the soil exposed and vulnerable to erosion agents such as wind and water[50].

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45 Adele Folino - Aimilia Karageorgiou - Paolo S. Calabrò - Dimitrios Komilis, "Biodegradation of Wasted Bioplastics in Natural and Industrial Environments: A Review", *Sustainability*, vol. 12, no. 15, July 2020, 6030; https://doi.org/10.3390/su12156030.

46 Ibid.

47 Tadahisa Iwata, "Biodegradable and Bio-Based Polymers: Future Prospects of Eco-Friendly Plastics", *Angewandte Chemie International Edition,* vol. 54, no. 11, March 2015, 3210–15; https://doi.org/10.1002/anie.201410770.

48 Tizazu Mekonnen - Paolo Mussone - Hamdy Khalilb - David Bressler, "Progress in Bio-Based Plastics and Plasticizing Modifications", *Journal of Materials Chemistry A*, vol. 1, no. 43, 2013, 13379; https://doi.org/10.1039/c3ta12555f.

49 Valentina Siracusa - Ignazio Blanco, "Bio-Polyethylene (Bio-PE), Bio-Polypropylene (Bio-PP) and Bio-Poly(Ethylene Terephthalate) (Bio-PET): Recent Developments in Bio-Based Polymers Analogous to Petroleum-Derived Ones for Packaging and Engineering Applications", *Polymers,* 12, no. 8, July 2020, 1641; https://doi.org/10.3390/polym12081641.

50 Belén Cárceles Rodríguez - Víctor Hugo Durán-Zuazo - Miguel Soriano Rodríguez - Iván F. García-Tejero - Baltasar Gálvez Ruiz - Simón Cuadros Tavira , "Conservation Agriculture as a Sustainable System for Soil Health: A Review", *Soil Systems*, vol. 6, no. 4, November 2022, 87; https://doi.org/10.3390/soilsystems6040087.

Unclear regulations and financial incentives

The adoption of biobased plastics within the packaging industry is hindered by unclear regulations and the absence of consistent financial incentives despite their potential to revolutionize sustainable packaging. The opinions of some interviewees are as follows:

Expert 2, "*Unclear regulations and the absence of consistent financial incentives can impede the widespread adoption of biobased plastics, despite the importance of recycling and the potential for incentives to offset production costs and drive sustainable packaging solutions."*

Scholar 4: "*Ambiguities in regulatory frameworks and the lack of enduring financial incentives may pose barriers to the extensive integration of biobased plastics within the packaging industry, despite the paramount role of recycling in waste reduction and the capacity of incentives to improve economic viability and the advancement of eco-friendly packaging solutions.*"

R&D Manager 2: "*Regulatory uncertainties and inconsistent financial incentives may impede the adoption of biobased plastics in packaging, despite the importance of recycling and incentives in promoting sustainable solutions.*"

Without clear guidelines and regulations, it becomes challenging for manufacturers and consumers to navigate the complexities of recycling biobased plastics. Incentives such as tax breaks, grants, and subsidies can encourage businesses to invest in biobased plastics and develop sustainable packaging solutions [38]. These incentives can help offset the higher production costs associated with biobased plastics and make them more competitive[51].

Discussion

The findings of this study, which aimed to reveal and examine the perspectives of various stakeholders regarding the potential of the shift toward bioplastic use in packaging, shed light on the awareness and level of information about the advantages and challenges of bioplastics. As argued and explained above, bioplastics are widely discussed since they are considered a promising alternative to fossil-based plastics. Given that waste management, the utilization of renewables, and the reduction of greenhouse gases are essential pillars of

51 Imke Korte - Judith Kreyenschmidt - Joana Wensing - Stefanie Bröring - Jan Niklas Frase - Ralf Pude - Christopher Konow - Thomas Havelt - Jessica Rumpf - Michaela Schmitz - Margit Schulze, "Can Sustainable Packaging Help to Reduce Food Waste? A Status Quo Focusing Plant-Derived Polymers and Additives", *Applied Sciences,* vol. 11, no. 11, June 2021, 5307; https://doi.org/10.3390/app11115307.

sustainability, developing alternative materials is a top agenda for researchers, producers, and policy-makers. In this context, the general level of awareness and knowledge indicated by the findings is predominantly consistent with the relevant literature. The stakeholders are well aware of the advantages and challenges of the transition to bioplastics from fossil-based materials.

The advantages of bioplastic packaging are numerous and of varying significance. From the perspective of stakeholder reduction in the carbon footprint, the advantageous chemical properties of bioplastics and biodegradation are the leading factors that make biobased materials more favourable regarding sustainability.

Biodegradation offers several advantages for biobased plastics as an EOL scenario. Biobased plastics present a reduced carbon footprint, demonstrate favourable material characteristics and have the potential to align with established recycling pathways[52]. Biobased plastics' biodegradability minimises plastic waste accumulation, provides opportunities for composting and anaerobic digestion, and promotes a circular economy[53].

The study's findings revealed a consensus among the stakeholders about the challenges of using bioplastics for packaging. Recycling is a significant problem by itself, along with its necessities. The challenges associated with recycling biobased plastic packaging include difficulty distinguishing between compatible polymers, the lack of suitable recycling infrastructure, low collection and recycling rates, consumer misconceptions, sustainability concerns, and the need for standards and regulations. Addressing these challenges requires collaboration among stakeholders, investment in recycling infrastructure, education and awareness campaigns, and the development of sustainable feedstock sources and recycling technologies.

Another challenge stakeholders are concerned about is the lack of standards and guidelines for using biobased materials. While ISO 14040 and EN 16760 provide valuable frameworks and guidelines for conducting LCAs and assessing the environmental performance of biobased plastics, there are criticisms regarding the heterogeneity in LCA approaches and assumptions. The variation

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52 Jan Georg Rosenboom - Robert Langer - Giovanni Traverso, "Bioplastics for a Circular Economy", *Nature Reviews Materials* (Nature Research), February 2022; https://doi.org/10.1038/s41578-021-00407-8.

53 Sarah Kakadellisa - Jeremy Woodsa - Zoe M Harrisa, "Achieving a Circular Bioeconomy for Plastics", *Resources, Conservation and Recycling,* vol. 169, 2021; https://doi.org/10.1016/j.resconrec.2021.105529.

in methodologies, data availability, and interpretation of results can limit the comparability and reliability of LCA studies. Efforts are being made to address these criticisms through harmonization initiatives and developing sector-specific guidelines to improve the consistency and credibility of LCA assessments for biobased plastic packaging.

The higher costs of biobased plastic packaging compared to fossil-based plastic packaging were also raised as a problem by the stakeholders. Increased costs can be attributed to renewable feedstocks, specialized manufacturing processes, limited economies of scale, and challenges in recycling and waste management. However, ongoing technological advancements and supportive policies can contribute to reducing these costs and improving the economic viability of biobased plastic packaging. Despite the emphasis in the literature on consumer behaviour regarding recycling issues, the stakeholders did not bring it up.

The findings showed that the stakeholders were both aware and knowledgeable about the impact of biobased materials on nature. The agricultural effects of biobased plastic packaging are complex and require careful consideration of both the positive and negative aspects. Although biobased plastics hold promise in decreasing greenhouse gas emissions and reducing reliance on fossil fuels, cultivating feedstocks and applying pesticides pose significant environmental implications. To ensure the sustainability of biobased plastic packaging, comprehensive sustainability assessments and the development of biodegradable materials are necessary.

The production of biobased plastics relies on water resources for crop irrigation and processing. Sustainable water management practices should be implemented in plastic biobased output to mitigate the potential negative impacts on water resources. This includes efficient irrigation techniques, such as drip irrigation, that minimize water waste and optimize water use[54]. Additionally, water recycling and reuse strategies can help reduce the overall water footprint of biobased plastic production[55].

54 Muhammad Sohail Memon - Kausar Ali - Altaf Ali Siyal - Jun Guo - Shamim Ara Memon - Shakeel Ahmed Soomro - Noreena Memon - Changying Ji, "Effects of Plastic Sheet on Water Saving and Yield under Furrow Irrigation Method in Semi-Arid Region", *International Journal of Agricultural and Biological Engineering,* vol. 11, no. 1, 2018, 172–77; https://doi.org/10.25165/j.ijabe.20181101.3186.

55 María Isabel Sánchez-Ruiz - Angel T. Martínez - Ana Serrano, "Optimizing Operational Parameters for the Enzymatic Production of Furandicarboxylic Acid Building Block", *Microbial Cell Factories,* vol. 20, no. 1, December 2021, 180; https://doi.org/10.1186/s12934-021-01669-1.

While the cultivation of feedstocks for biobased plastic packaging can involve the use of pesticides, fertilizers, and other agrochemicals, alternative feedstock options can mitigate the use of pesticides and fertilizers. Secondary nonedible byproducts or third-generation algae can represent more sustainable options as feedstocks in the production of biobased plastics[56].

Sustainable agricultural practices should be implemented to mitigate the risk of soil erosion associated with large-scale cultivation of biobased plastic feedstocks. Conservation agriculture, which involves minimal tillage, cover cropping, and crop rotation, has been shown to improve soil health and reduce soil erosion[57].

Additionally, using phosphate-solubilizing biofertilizers can enhance soil fertility and nutrient availability, contributing to better soil structure and reducing the risk of erosion [43]. Implementing erosion control measures, such as terracing or contour ploughing, can also help mitigate soil erosion in areas where intensive agricultural practices are used[58].

The environmental ramifications of plastics, encompassing biobased variants, transcend mere greenhouse gas emissions. Extensive accumulation of plastics has been identified in landfills and natural ecosystems, resulting in physical hazards to wildlife due to ingestion or entanglement[59]. Furthermore, concerns have emerged regarding the leaching of chemicals from plastics into the surrounding environment[60]. Thus, the evaluation of the sustainability of biobased plastics

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56 Arianna Rech - Efthymios Siamos - Paul Nicholas - Anders E. Daugaard, "Recyclable Extrudable Biopolymer Composites from Alginate and Lignocellulosic Biomass Waste", *ACS Sustainable Chemistry & Engineering,* 11, no. 24, June 2023, 8939–47; https://doi.org/10.1021/acssuschemeng.3c01119.

57 Belén Cárceles Rodríguez - Víctor Hugo Durán-Zuazo - Miguel Soriano Rodríguez - Iván F. García-Tejero - Baltasar Gálvez Ruiz - Simón Cuadros Tavira , "Conservation Agriculture as a Sustainable System for Soil Health: A Review", *Soil Systems,* vol. 6, no. 4, November 2022, 87; https://doi.org/10.3390/soilsystems6040087.

58 Pierre-Alexis Chaboche - Nicolas Saby - J.Patrick Laceby - Jean P.G. Minella -Tales Tiecher - Rafael Ramon - Marcos Tassano - Pablo Cabral - Mirel Cabrera - Yuri Jacques - Agra Bezerrada Silva - et.al, "Mapping the Spatial Distribution of Global 137Cs Fallout in Soils of South America as a Baseline for Earth Science Studies", *Earth-Science Reviews,* 214, March 2021, 103542; https://doi.org/10.1016/j.earscirev.2021.103542.

59 Richard C. Thompson - Charles J. Moore - Frederick S. vom Saal - Shanna H. Swan, "Plastics, the Environment and Human Health: Current Consensus and Future Trends", *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364, no. 1526, July 2009, 2153–66; https://doi.org/10.1098/rstb.2009.0053.

60 Ibid.

necessitates a thorough assessment of their environmental impacts, including considerations of waste buildup, impacts on wildlife, and the potential for chemical leaching.

Various factors influence the environmental impact of biobased plastic production, and a comprehensive assessment of the entire life cycle is necessary to evaluate its sustainability.

Large-scale cultivation of biobased plastic feedstocks can increase the risk of soil erosion, especially in areas where intensive agricultural practices are employed. However, sustainable agricultural practices, such as conservation agriculture and biofertilizers, can help mitigate this risk and promote soil health and fertility. It is crucial to prioritize adopting these practices to ensure the long-term sustainability of biobased plastic production and minimize the environmental impacts associated with soil erosion.

The cultivation and processing of biobased plastic feedstocks can generate greenhouse gas emissions, although the extent of these emissions depends on various factors. Biobased plastics offer a low-carbon method of plastic production and can reduce life cycle greenhouse gas emissions compared to fossil-based plastics. However, the sustainability of biobased plastics should be evaluated based on a comprehensive assessment of their environmental impacts, including waste accumulation, wildlife impact, and chemical leaching. Strategic decision-making regarding the use of biobased plastics should consider the trade-offs between their environmental benefits and potential negative consequences.

The last challenge the stakeholders involved in this study mentioned was the unclear regulations that eased the shift to biobased materials in packaging and the insufficient financial incentives.

Conclusion

This study, consisting of data analysis and a literature review, revealed that transitioning to bioplastics in the packaging industry has great potential to achieve sustainability goals. However, the challenges mentioned by the stakeholders and supported by previous research should not be underestimated to reach the potential of this transition. Multifaceted difficulties should be addressed with an interdisciplinary approach to avoid facing new challenges. Scientific research, R&D, production, and consumer studies should go hand-in-hand since the issue concerns many sectors and society.

Limitations and Future Research Implications

This study's sample for data collection was theoretically chosen due to the research design. Therefore, the findings based on the data collected from major stakeholders may not cover all perspectives on the research topic. Consequently, the results cannot be generalized to other groups of actors involved in the transition to bioplastic packaging, such as members of environmental NGOs and government officials.

As previously noted, transitioning from fossil-based plastics to biobased materials within the packaging industry represents a pivotal step toward attaining sustainability objectives. Nevertheless, effectuating this transition encompasses more than just the manufacturing of biobased packaging; it also necessitates a shift in consumer behaviour. Hence, it is important to research consumer preferences and perceptions about packaging materials.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

While preparing this work, the authors used Notion.ai and ProWritingAid to spell and check grammar. After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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Araştırmacıların Katkı Oranı

Araştırmacıların her birisinin mevcut araştırmaya katkısı %50 oranındadır.

Çatışma Beyanı

Araştırmada herhangi bir çıkar çatışması bulunmamaktadır.