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What Hinders the Development of a Sustainable Compostable Packaging Market?

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Abstract
Numerous publications and expert reports indicate plastic pollution as a widespread environmental problem. About 10 million tonnes of litter end up in the seas and oceans each year. It is estimated that 80% of all litter in saltwater is mainly plastic food packaging. Facing this challenge compostable packaging seems to be an alternative to conventional plastic ones and a feasible solution. Despite the environmental opportunities of the packaging produced from bio-based biodegradable polymers, the compostable packaging market is growing relatively slowly. Therefore, the aim of the paper is to recognize the key factors hindering the expansion of the food compostable packaging market for sustainable development. To achieve this objective 29 in-depth interviews with respondents of the key groups of biopackaging market stakeholders were conducted. The results of the qualitative study allowed us to identify environmental, economic, social, and governance barriers in the light of four main problems disrupting compostable packaging market development. This is an important contribution to the business and academic discussion on the importance of compostable packaging in achieving sustainable development goals as well as implementing the circular economy concept. The paper is the effect of the international R&D project.

Keywords: bio-based biodegradable packaging, compostable, packaging sector, sustainable development, Quadruple Bottom Line, plastic pollution

1. Introduction

Today's economy is heavily dependent on non-renewable resources. In recent decades, environmental exploitation has accelerated due to the need to meet the expectations of the growing population and the consumer society. As a consequence, we are witnessing significant climate change, loss of biodiversity, and global pollution of the natural environment (Asgher et al 2020). The considerations in the article concern the priority problem of plastic waste, which is generated in enormous amounts each year and ultimately ends up in, among others, the waters of the seas and oceans. This disturbs the balance of aquatic ecosystems. It is estimated that 80% of all litter in saltwater is plastic, mainly food packaging (. Sea animals not only get entangled in it but also swallow it, allowing chemicals and microplastic in the waste to penetrate the food chain, affecting the health of the human being at its end (European Commision 2013, p. 6-7). The world is not indifferent to the situation and, in response, strengthens the effectiveness of the implementation of the assumptions of sustainable development (SD), establishing, inter alia, 17 Sustainable Development Goals for the next fifteen years (United Nations, 2015). The main source of plastic waste in the European Union (EU) is packaging (European Commision, 2018, p. 2). Therefore, in recent years, a number of normative documents

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have been created to regulate the packaging management in the Member States according to the circular economy principles e.g. Directive 2019/904, Directive 2018/851, A European Strategy for Plastics in a Circular Economy (European Commission 2018). The food packaging market sees the negative impact of conventional packaging on the natural environment and is looking for new environmentally friendly solutions. Consequently, in recent years, the potential of bio-packaging, especially compostable packaging, has gradually been recognized as possibly the greenest alternative to fossil-based plastic packaging. The dominant view in the literature is that compostable packaging is used primarily for food and medical products (Combrzynski et al. 2020, Saalah et al. 2020)
The presented considerations focus on bio-based biodegradable packaging. Considering contemporary environmental, social, and economic challenges, it becomes necessary to introduce such innovations that will implement SD objectives in the most effective way. Therefore, the aim of the paper is to recognize the key factors hindering the expansion of the compostable food packaging market for sustainable development. It is recognized that so far the issues related to the development and commercialization of compostable packaging in the food sector have been described fragmentarily in past research. Therefore, this article contributes to the literature as it presents a comprehensive and in-depth analysis of the problems to the development of compostable packaging in accordance with contemporary challenges, referring to the wider approach, which is Quadruple Bottom Line (QBL).

2. Theory background

2.1. Four dimensions of sustainable development

SD covers three evolving dimensions: environmental, economic, and social (Elkington, 1998). These pillars constitute the Triple Bottom Line concept (TBL) which is "a sustainability framework that examines a company's social, environmental, and economic impact" (Elkington, 2018). Although it was a milestone in the development of the idea of sustainability measurement, it was followed soon by the Quadruple Bottom Line (QBL), which included an additional area - governance (Woodward et al. 2004). SD and QBL concepts concern the risks of changing climate conditions on earth manifested in more frequent and severe weather events, e.g., heat waves, drought, storms, flooding, warming oceans, melting glaciers, and rising sea levels. Climate change ultimately leads to the destruction of people's livelihoods and communities, and the extinction of plant and animal species. Kikstra et al. (2021) underline that taking action against climate change is urgent and the urgency is expressed in "the social cost of carbon dioxide" representing "the total welfare lost across the globe" resulting from the emission of an additional tonne of CO2 (Kikstra et al. 2021). Climate change makes society vulnerable to the risk of inhibiting economic growth linked to the risk of deteriorating social conditions. The World Economic Forum in The Global Risk Report 2021 indicated the most important types of global risk, broken into five categories: economic, environmental, geopolitical, social, and technological. The threats most likely to occur in the next ten years are extreme weather events, climate failure, and man-made environmental damage, as well as the concentration of digital power, digital inequality, and cyber-security failure. Over the next decade, the most impacting will be communicable diseases, climate failure, and other environmental

threats, the proliferation of weapons of mass destruction, livelihood crises, debt crises, and IT infrastructure failures (WEF, 2021).

Globalization and increased consumption bring new challenges (opportunities, but also threats) for companies. We can observe increasing social pressure on companies and their adaption to the rules of SD (Jaramillo et al., 2018; Galvão et al. 2022). On the other hand, there are several social, economic, and environment-related trends causing sustainable development challenges: all sorts of inequalities, globalization, environmental degradation, and a fast-growing population (Imasiku, 2021).

Developing an appropriate response to the diverse risks resulting from climate change is a challenge facing businesses and governments alike. They require, on the one hand, changes to business models and corporate governance and, on the other, an appropriate transparent legal environment and standards that keep pace with market needs in terms of both content and time relevance. Circular economies require effective governance both on the corporate and the public levels (Cramer 2022).

2.2. Compostable packaging market

There are four groups of polymers that can be used for packaging manufacturing. Today, the most popular group is represented by fossil-based and non-biodegradable polymers (Figure 1, Group III). It mainly consists of PET (poly (ethylene terephthalate), PP (polypropylene), PS (polystyrene) and PE (polyethylene).

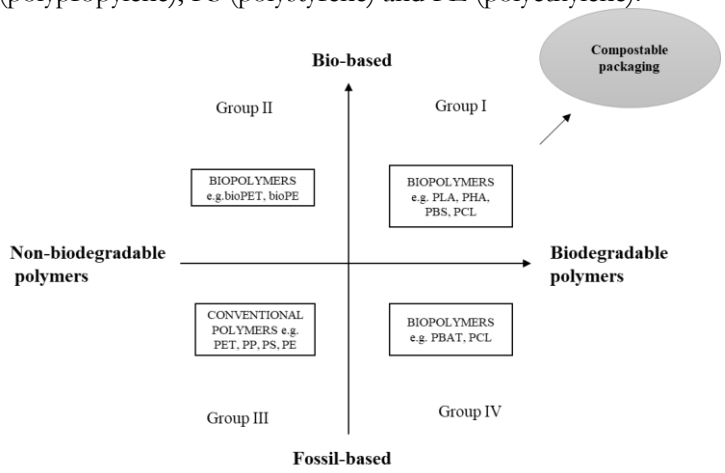

Figure 1. Compostable packaging in the light of four groups of polymers.
Source: own study on the base of European Bioplastics (2018).

Nowadays, the packaging made of them is an increasing problem in the context of environmental pollution with plastic waste, climate change and shrinking non-renewable resources. Currently, the most ecological alternatives to conventional packaging are being searched for (Arikan and Ozsoy 2015, Shamsuddin et al. 2017). They have different properties, thus limitations in use (Stoleru, Irimia and Butnaru 2021). One of alternatives is compostable packaging made of bio-based biodegradable polymers, e.g., polyactide (PLA) or polyhydroxyalkoxide (PHA) with properties similar to traditional PET or PP (Bukowska-Śluz 2004, Foltynowicz and Jakubiak 2004, Šprajcar, Horvat and Kržan 2012). The use of such materials, on the one hand, ensures their biodegradability and, on the

other hand, means that their sources are renewable, which in recent years has been of particular importance for environmental policy. According to the EN 13432 standard (European Committee for Standardization, 2000), the compostable packaging is converted to CO_2 of at least 90% within 6 months. During the aerobic composting process, in addition to carbon dioxide, water and biomass are also produced (Sikorska et al., 2019).
As the compostable packaging market is still small, no statistics have yet been gathered on the national level. However, in industry publications, one can find some forecasts regarding the biodegradable packaging market. For example, in 2025, the share of these packaging will amount to 10%, with the overall share of plastic packaging at 37.5% (Polish Chamber of Packaging, 2019).

3. Literature review on compostable packaging in the context of sustainable development

When analysing the issues of compostable packaging in the SD context, four dimensions should be considered following the QBL concept: environmental, economic, social, and governance.
The **environmental** perspective is central in the literature on compostable packaging.
For the development of sustainable compostable packaging and management of its life cycle in accordance with the circular economy principles, it is particularly important to distinguish between 'compostable' and 'biodegradable' terms (Barker and Safford 2015, Varžinskas and Markevičiūtė 2020). Compostable packaging should meet specific requirements that ensure that after its decomposition, compost is created that is safe for human health and ecosystems (Thakur et al 2018) and possible to use in agriculture. Therefore, proper chemical characteristics and ecotoxicity of compostability (e.g., lack of microplastic) determine the positive environmental impact and quality of the final product whereas, disintegration and biodegradation ensure the proper course of the composting process (De Wilde 2002, Varžinskas and Markevičiūtė 2020). This approach also supports the management of the compostable packaging life cycle in accordance with the principles of the circular economy. At the same time, it highlights the role of an efficient waste management system that will direct the waste stream of compostable packaging to bio-waste and then to the composting process. The composting process can be not only aerobic but also anaerobic, which leads to the formation of biogas as an energy source.
Interestingly, the literature on the subject recognizes that compostable packaging is also a potential source of environmental risks to sustainable development. First, their positive impact on the natural environment is not fully recognized. There is still a discussion about whether or not bio-based materials are environmentally friendlier options compared to plastics in terms of the Life Cycle Assessment (Khoo, Tan and Chng 2010). Secondly, although bio-based plastics can have a lower carbon footprint compared with fossil-based plastics, they might have a negative agricultural impact and reduce raw material reserves as they are produced from renewable sources. Thus, they represent potential competition with food production (Arikan and Ozsoy 2015, Rosenboom et al., 2022).
From the **economic** perspective, renewable raw materials for packaging production are seen as an enabler of the transition from a linear to a sustainable bioeconomy (Paraschiv et al., 2020; Vinskas and Markeviciute, 2020). The perspective of the entire packaging lifecycle including eco-design needs to be adapted to empower the above-mentioned transition, address socio-economic criteria of compostable packaging, and reduce

environmental impact (Paraschiv et al., 2021). The compostable packaging market needs substantial investments i.e., in switching production plants, and financing R&D initiatives (e.g., developing new materials), especially during the trial period where multiple testing of new solutions is necessary (Paraschiv et al., 2020; Cacciotti et al., 2018). The authors argue that R&D activities should aim at the reduction of compostable packaging production costs and developing viable business models. Arikan and Ozsoy (2015) note that compostable packaging is, on average, two times more expensive compared to conventional plastics. This view is shared also by Rosenboom et al. (2022), Muthuraj, Misra, and Mohanty (2018). This price difference results from the following four cost drivers: (1) expensive biopolymer plant construction, (2) high costs of raw materials, (3) lack of economies of scale, (4) costly research and development activities (Arikan and Ozsoy 2015). Rising demand for fuel and energy sources are trends that favor the development of the compostable packaging market (Varžinskas and Markevičiūtė 2020, Barker and Safford 2015). So far, compostable packaging does not yet meet producers' and consumers' needs and expectations to the full extent (Varzinskas and Markeviciute, 2020; Rosentrater et al., 2019). On the one hand, consumers' purchasing decisions are determined by "the attractiveness, perceived quality, and eco-friendliness of the packaging" (Testa et al. 2021). On the other hand, Brockhaus, Petersen, and Kersten (2016) indicate consumers' behavioral challenges i.e. uncertainties of customer receptiveness towards compostable packaging.

The **social** and **governance** perspectives are less explored in the literature. Paraschiv et al. (2020) argue that the implementation of compostable packaging, although needed, is problematic due to the lack of civic spirit manifested in behavioural and waste collection problems. Compostable packaging needs to be uniquely defined in the context of bioplastics (Taufik et al. 2020, Sijtsema et al., 2016)) and clearly labeled to support consumers in behavioral change (Allison et al. 2021), more sustainable purchasing decisions and the sorting process (Paraschiv et al. 2021). Rising concerns about food waste in face of world demand for food is also an important challenge and packaging may play an important role in minimizing food waste in the supply chains (Varzinskass and Markeviciute 2020, Garcia-Garcia et al. 2017, Verghese et al. 2015). Varžinskas and Markevičiūtė (2020) argue that the parallel use of several different terms to describe compostable packaging is also a limitation (e.g. bio-based, bio-degradable, compostable) and results in confusion and misunderstanding. Testa et al. (2021) draw attention to a lack of consumer knowledge is also an important impeding factor hindering the development of compostable food packaging.

From the governance perspective, Clark, Trimingham, and Storer (2019) indicate the vulnerability of legislation and tax system as an important factor, that influences the growth rate of the compostable packaging market. Ciriminna and Pagliaro (2020) pay particular attention to the need of creating knowledge and its transfer to the compostable packaging market which suffers from a shortage of skilled workforce. To foster the above-mentioned changes, "countries should proactively act by establishing new bioeconomy research and educational institutes able to give also more useful policy advice" (Ciriminna and Pagliaro 2020). The successful implementation of compostable packaging requires establishing an effective system for the collection, sorting, and management of the packaging waste. This is an issue at the intersection of social and governance perspectives. Packaging waste

management systems need to be revised to serve organic waste, including compostable packaging, properly, e.g., support for industrial composting (Razniewska 2022). Paraschiv et al. (2021) point to the special responsibility of the state governments for setting the regulatory framework supporting the development of the compostable packaging market and increasing its transparency and standardization. On the one hand, there is also the aforementioned need to educate consumers in this area (Paraschiv et al. 2021, Taufik et al. 2020), and on the other hand, a need to provide appropriate infrastructure and integrated policies, regulations, and standards supporting waste management (Saalah et al. 2020, Borrello et al. 2016).

4. Methodology

Research on barriers to the sustainable compostable packaging market development is an integral part of research conducted in a global project, representing a total of four countries on three continents. The bio-packaging market in Poland is very young, which is related to the small number of its participants. In order to capture the issue of factors hindering the management of compostable packaging in accordance with the concept of SD, it was decided to conduct a qualitative study using the IDI (in-depth interview) method. IDIs involved representatives of various the internal and external supply chain stakeholders, both form private and public sectors (Appendix 1). The study consisted of several steps procedure (Table 1).

Table 1. Characteristics of the study

Research period	01.09.2020 – 31.04.2021
Research method	In-depth Interview
Number of IDIs	29
Research procedure	1. Market identification and development of a database of market participants 2. Sending invitations to the stakeholders of bio-packaging market 3. First meeting (30 min.) 4. Second meeting – IDI (60-90min.) 5. Transcription of each interview 6. Analysis of collected data
Question types	Open
Contact	Online
Communication tool	Zoom, MS Teams
Participants	Suppliers of raw materials and bioplastics, packaging manufacturers, packaging distributors, business customers, food manufacturers, consumers, waste management entities, organizations for standardization and certification, research and development institutions, public administration institutions and non-governmental entities.

Source: own study.

As there are no available databases of the bio-packaging market participants in Poland, it was necessary to recognize the market in the first place. This made it possible to reach various stakeholder groups to whom the invitations to participate in the study were addressed. Two meetings were scheduled for the research procedure. The first meeting

was aimed at presenting the assumptions of the conducted market diagnosis, establishing cooperation with stakeholders, and obtaining final consent to participate in the study. It was a Zoom meeting and lasted about 30 minutes. The second meeting was an in-depth Interview (IDI) conducted via MS Teams. For its needs, unique open questions were created, which covered, inter alia, barriers (hindering factors) to the development food compostable packaging market. The collected data were subjected to a detailed analysis process (Figure 2).

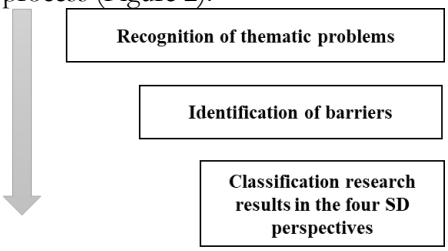

Figure 2. The research data analysis process.
Source: own study.

The analysis resulted in the identification of 16 barriers concerning revealed four thematic problems (Marzantowicz and Wieteska-Rosiak 2021). Subsequently, all the barriers were systematized in the light of each SD perspective: environmental, economic, social, and governance (Table 3).

5. Results

The results of the study allowed us to identify 16 barriers to the development of the bio-packaging market, and then present these barriers in terms of the main dimensions of sustainability. According to the results, all barriers were related to the environmental, governance, social, and economic aspects (Table 3). The largest number of barriers is related to the government dimension, whereas for the environmental dimension there were no barriers pointed out by the interviewed stakeholders.

Table 3. Barriers to the development of the bio-packaging market in environmental, governance, social and financial dimensions of SD.

Problem	Barriers	Dimension
I. A low share of bio-packaging (incl. compostable packaging) in the market food packaging in Poland	High market prices of compostable packaging in relation to the prices of conventional plastic packaging	Economic
	Limited properties of bio-packaging in relation to conventional plastic packaging	Economic
	A lack of support to level the playing field for compostable packaging	Governance
II. A low awareness and consumers' tendency to buy	An insufficient level of consumer knowledge about bio-packaging in the circular economy	Social

Problem	Barriers	Dimension
food products in compostable packaging	A low social commitment to circular waste management	Social
	The poorly developed infrastructure supporting the selective collection of packaging by consumers	Governance
	Greenwashing in the food bio-packaging market (from the consumer perspective)	Governance
III. An insufficient social and environmental enterprise responsibility in packaging supply chains for a circular economy	Insufficient integration of economic, environmental, and social goals into one main sustainable goal	Governance
	A lack of the link between investor assessment and corporate sustainability, including the approach to managing packaging in an environmentally responsible manner	Economic
	A lack of sufficient cooperation of enterprises for the benefit of circular economy in the field of, i.a., design, and development of the food bio-packaging, including compostable packaging	Economic / Governance
	A lack of social pressure on the implementation of environmentally and socially responsible activities by enterprises	Social
	Greenwashing in the food bio-packaging market (from the perspective of companies)	Governance
IV. A low level of development of compostable packaging waste management	Lack of uniform and transparent regulations regarding the planning and organization of the closed-loop compostable packaging	Governance
	Insufficient communication between the private and public sectors on how to increase the use of food compostable packaging	Governance
	Poorly developed compostable waste management system	Governance
	Lack of sufficient financial incentives to support activities for the benefit of the circular economy of compostable packaging at the level of local government units	Governance

Source: own study.

The first problem recognized during the research is a **low share of bio-packaging (incl. compostable packaging) in the market of food packaging in Poland.** It covers the three main barriers related to the economic and governance dimensions of SD (Table 3, barriers: 1,2,3). The prices of raw materials for compostable packaging production are 3.5 times higher than the prices of raw materials for conventional packaging production. It is especially related to the low availability of imported and domestic raw materials to produce bio-packaging. Additionally, in the supply chains of compostable packaging, the logistics

and production processes are also costly due to the very limited possibilities of achieving economies of scale considering low demand as well as the time-consuming and cost-intensive certification process. Insufficient properties of compostable packaging are the effect of still low level of development of eco-innovation in packaging. There is also a lack of integration of knowledge and resources of stakeholders in the bio-packaging supply chain as well as limited access to specialist knowledge on the production of bio-packaging. Further, the processes of developing eco-product innovations are also not adequately supported by legal regulations. There is also a lack of financial incentives for the market participants to support the development and introduction of bio-packaging according to the circular economy principles. The low competitiveness of compostable packaging is also the result of difficulties in their identification and the lack of an effective system to control the segregation of bio-waste. Both issues are related to low consumer awareness of the importance and availability of compostable packaging in the country.

Problem number two identified in the course of the research procedure is a **low awareness and consumers' tendency to buy food products in bio-packaging**. It includes the main four social and governance barriers (Table 3, barriers: 4,5,6,7). The problem persists because of the still evident deficit of consumer knowledge and awareness about the contribution of excessive packaging use to high environmental pressure. There is a lack of multi-channel education about compostable packaging and waste management at different education levels (e.g., in schools, social media, through mobile applications etc.), as well as nationwide (public, private, social) information or education campaigns targeted at specific social groups. Moreover, there is also an apparent lack of involvement of businesses in providing reliable information and educating consumers, e.g. compostable packaging lacks visible and understandable information on labels.. The lack of knowledge and awareness entails public reluctance and resistance to changes in waste management, low commitment, and low culture of waste segregation. Workshop participants mentioned the limitations of household as well as public infrastructure for waste segregation and collection.. An important reason is also low consequences for households not aligning with the waste segregation rules. There are also important challenges on the municipality level. Additionally, uncertainty about legal and technological changes in the field of waste segregation in the coming years makes it difficult to make investment decisions regarding specific infrastructural solutions. Furthermore, there is also a lack of appropriate systems for the collection of compostable packaging waste from the perspective of their further processing. This is accompanied by the reluctance of municipalities to accept compostable packaging and the lack of consent to place compostable packaging in bins with bio-waste. The greenwashing practices deepen the above barriers.

The third problem, which is an **insufficient social and environmental enterprise responsibility in packaging supply chains for the circular economy**, consists of the following five barriers (Table 3, barriers: 8,10,11,12). The occurrence of the above barriers is related to a lack of competence and experience of enterprises in the issues of closed-loop economy and compostable packaging; no reliable, universal, and systematized sources of information and knowledge on compostable packaging; companies' reliance on information from their own suppliers that may not be objective; circular economy issues being assigned to inappropriate units (e.g. marketing); the education system not covering the needs for the circular economy and compostable packaging competencies; an

inconsistent concept of extended producer responsibility - no financial responsibility (organizational only), a lack of strategic approach to packaging on company level including a lack of interdisciplinary packaging design teams; a strong competition in the compostable packaging market and a lack of cooperation between companies due to losing know-how concerns; low consumer interest in food products in compostable packaging due to their higher price and at the same time a relatively low consumer disposable income. It should be emphasized that greenwashing practices are widely accepted, which does not support building social awareness. It is a very complex barrier due to the lack of unified legal regulations against greenwashing practices, the lack of available tools for identifying and verifying unfair practices, as well as the lack of consumer awareness of exposure to greenwashing resulting from the trust in a certain brand or a product.

The last problem, which is a **low level of development of compostable packaging waste management** concerns four government barriers (Table 3, barriers: 13,14,15,16). In Poland, there is a noticeable change in regulations in the field of packaging and legal waste management, strengthened by regulations transposed from the European Union level. Effective and timely implementation of the pro-environmental policy is hampered by at least two factors. First, there is a lack of administrative officials specializing in the issue of SD and circular economy. Secondly, there is a lack of cooperation between the legislator and business in the legislative process. Insufficient communication result from a strong lobby of producers of conventional packaging, a lack of willingness to include the needs of market participants in compostable packaging, and on the other hand from an uneducated culture of cooperation between the administration and the private sector and the shortage of communication tools between the public and private sectors. The situation is made difficult by the lack of unambiguous markings on the packaging, enabling their proper segregation, and the lack of quality control of bio-waste provided by consumers. The problem is amplified by human factors, such as low consumer awareness of separate bio-waste collection as well as a lack of clear regulations on managing biowaste in Poland. Finally, there is a lack of investment financial outlays on the composting infrastructure due to the still little interest in its use and the lack of treatment of the issue of developing sustainable compostable packaging as an investment priority.

6. Discussion

To properly discuss the factors hindering the development of sustainable compostable packaging in the light of the research results and the literature on the subject, the consideration needs to be conducted in relation to each of the SD dimensions. The discussion will follow the QBL concept of four dimensions: environment, economic, social, and governance. Although there are no comprehensive studies in the literature precisely showing factors hindering the sustainable compostable packaging market development, in there are some previous studies referring to general barriers included in the conducted research.

It should be emphasized that the surveyed organizations indicated concern for the natural environment as the main factor motivating rather than hampering the introduction of compostable packaging. Producers and distributors declare their willingness to increase the share of compostable packaging in the market as an opportunity to reduce the volume

of pollution with plastic waste. In this light, only environmental issues were not indicated as barriers. It can be deduced that for enterprises, the discussion around the LCA of compostable packaging, is not as important as in the scientific community. Most likely because there are no unequivocal data and clear position among scientists in this regard (Khoo, Tan and Chng 2010, Arikan and Ozsoy 2015, Rosenboom et al., 2022). Therefore, against the background of previous research and the results obtained, it can be concluded that the stakeholders believe that the need to minimize the plastic pollution weight more than the doubts about the LCA of compostable packaging. It is worth adding that in the light of the decreasing access to food, as a result of Russia's aggression against Ukraine, the potential competitiveness of the packaging market to the food market may strengthen. This kind of competitiveness was already emphasized in the literature on the subject (Arikan and Ozsoy 2015, Rosenboom et al., 2022).

The research showed that from the social perspective, the main challenge is to overcome a low awareness of consumers. Stakeholders' representatives taking part in the research workshops indicated the lack of awareness among consumers about the significance and scale of the problem with packaging waste management. In this respect, the study's results confirmed the conclusions that can be found in the literature (Paraschiv et al. 2020, Tesa et al. 2021, Allison et al. 2021). There is still a noticeable deficit in consumers' knowledge and awareness about the problem of excessive use of packaging which contributes heavily to the high pressure on the natural environment. It is visible in a low social commitment to circular waste management. This view is also supported by the research results of Testa et al. (2021) and Taufik et al. (2020) who advocate the requirement for communication and information transfer toward consumers. The study shows that a lack of knowledge and awareness translates into w lack of social pressure on the implementation of environmentally and socially responsible activities by enterprises. The need for consumer education on compostable packaging and waste management through nationwide information campaigns is one of the pillars for further development of the compostable packaging market. Therefore, it is necessary to specify the target group at which educational or information activities are directed. Each of the consumer groups, including the X, Y, and Z generation, is specific and requires the use of appropriate channels and methods of communication. Allison et al. (2021) confirmed this view concluding that behaviour change will be a key component of any solution. Considering the current geopolitical situation and the economic crisis resulting in high inflation and price increase in many countries, the consumers' interest in sustainable compostable packaging is at risk due to its non-competitive prices so far compared to conventional plastic packaging.

High market prices of compostable packaging in relation to the prices of plastic packaging, is an important economic barrier to the development of the compostable packaging market indicated by stakeholders. The research results in this respect fits in results of previous research presented in the literature. Many authors elaborate on this fundamental economic factor (i.e., Vinskas and Markeviciute 2020, Barker and Safford 2015, Rosenboom et al. 2022, Muthura, Misra, Mohanty 2018) resulting from high costs of polymers, a small number of suppliers of the corresponding raw materials from renewable sources, high investment requirements to develop or adapt production infrastructure, high costs of R&D activities, to name a few.

Limited properties of bio-packaging in relation to conventional plastic food packaging is another important barrier also indicated by Varzinskas and Markeviciute (2020) and by Rosentrater et al. (2019). Stakeholder representatives also presented the view that a lack of sufficient cooperation of enterprises for the benefit of circular economy in the field of, i.a., design, R&D exacerbates the difficulty for them to achieve economies of scale. Companies lack a strong stimulus, both from the regulatory environment and from investors, to actively address circular economy concept in business goals, strategy and operations. There is a noticeable lack of the link between investor assessment and corporate sustainability, including the approach to managing packaging in an environmentally responsible manner. The analyzed literature does not elaborate on this issue.

According to the research results, governance barriers constitute a significant risk disturbing the development of the compostable packaging market for SD. This is in line with previous studies on factors hindering sustainable development, CE principles implementation and effective waste management. All recognized barriers address four thematic problems. One of the reasons for insignificant share of bio-packaging in the food packaging market in Poland is lack of support to level the playing field for bio-based packaging. Such support may refer to both tax breaks and financial support in the area of product innovation development. For the success of closing the life cycle of compostable packaging in accordance with the principles of circular economy, the role of administration at the central and local levels is particularly important (Paraschiv, Hubel and Stanciu 2021).

A properly designed waste management system is of key importance for the use of the environmental potential of compostable packaging. Compostable waste may present a risk of contamination of other waste streams (Varžinskas and Markevičiūtė 2020, Paraschiv, Hubel and Stanciu 2021). Even more so, the lack of social awareness, the lack of proper marking of compostable packaging and the ineffective use of organic recycling constitute a barrier to the development of sustainable compostable packaging. Further, the research results show that both infrastructure supporting selective collection of packaging by consumers and compostable waste management system are still poorly developed.

According to Arikan and Ozsoy (2015), although the production of bioplastics is increasing still, many countries have not introduced any law or legislation regarding their production, usage, or waste management. The need for a regulatory system that would be unambiguous and simplified for use was also noticed in other countries, e.g., Romania (Paraschiv, Hubel and Stanciu 2021). The extended responsibility of the manufacturer should also carefully cover managing compostable packaging (Paraschiv, Hubel and Stanciu 2021). Nevertheless, stakeholders have doubts whether it sufficiently supports the sustainable compostable packaging market development in Poland.

Finally, it is worth referring to the problem of greenwashing, which is very strong in Poland in the food bio-packaging market. Similar problems are reported in other countries (Zhu and Wang 2020, Peng, Gao and Chen 2021). Greenwashing presence is strengthened by unclear legal regulations (e.g., lack of clear definition of compostable packaging for the Polish market), but also by the lack of a systemic approach to the management of compostable packaging. This greenwashing is mainly generated by the private sector, taking advantage of the lack of consumer knowledge and insufficient legal regulations.

6. Conclusions

According to the respondents, compostable packaging does not generate risk in relation to the environmental dimension of SD. They agree that a prerequisite for further development of the market is the introduction of regulations that clearly define the priorities in the long term. This would be a strong signal for companies to continue bolder investments. Thus, the public sector has a huge role in supporting business development and innovation and the waste management system. Regulations should be subordinated to the national strategy for the development of a circular economy, including bio-packaging. Time is of the essence in this regard, as solutions are currently being developed at the European Union level thus there are fewer and fewer opportunities for co-creation of the regulatory environment by compostable packaging market stakeholders. These provisions will have to be implemented at the national level. This is of great importance in the light of the fight against greenwashing and stimulating the environmental responsibility of companies operating in the domestic market. The study identified four solutions that could support market growth: a national strategy for the development of the compostable packaging market, stakeholder education, an industry organization, and a technology platform supporting the integration of bio-packaging supply chain stakeholders.

The study has practical and theoretical implications. Firstly, the research resulted in recommendations on how to support the development of the compostable packaging market so that it can achieve the goals of SD and take into account QBL dimensions. Secondly, it provided a comprehensive assessment of possibilities of the development of compostable packaging in accordance with contemporary challenges, also referring to QBL. The conducted study, thanks to the application of the in-depth interview method, allowing for a detailed analysis of four problems hindering the development of the compostable packaging market. The research shows that these problems are specially of an economic, governance and social nature. This means that stimulating the sustainable development of the compostable packaging market requires multidimensional and multidirectional activities, both top-down and bottom-up. The results of the study, due to their comprehensiveness, are consistent with specific previous studies. However, they also provide new value in the form of unique in-depth analysis, the effects of which can also be applied in other countries. The global compostable packaging market is still relatively young; however, it is expected that it will gradually grow in the future. Therefore, the identified 16 barriers constitute a comprehensive guide both for public administration and enterprises on preventive and reactive measures that need to be taken to stimulate market development according to the sustainable development objectives and CE principles. While we are convinced that the research study brings added value both in science and in practice, we are aware of its few limitations. The first limitation may be a qualitative approach which could be supplemented with quantitative research in the future when the market develops. The second one may be the limitation of the research study to one country. However, it is worth emphasizing, that the bio-packaging market is at a similar stage around the world.

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Appendix 1 Characteristics of the study participants

Interview no.	Type of market participant	Respondent's position	Sector	Capital
1	Packaging manufacturer	Member of the Board	private	national
2	Packaging manufacturer	Owner	private	national
3	Packaging manufacturer	Marketing specialist	private	national
4	Packaging manufacturer	Two owners	private	national
5	Packaging manufacturer	R&D Director	private	national

6	Supplier of raw materials and bioplastics	Brand Development Director	private	national
7	Gardening company	Owner	private	national
8	Packaging distributors	Regional Sales Manager	private	foreign
9	Packaging distributors	Commercial Director	private	national
10	Packaging distributors	Two owners	private	national
11	Packaging distributors	Quality Assurance Specialist	private	national
12	Packaging distributors	Director	private	national
13	Individual clients	Consumer, blogger	-	-
14	Individual clients	Consumer,	-	-
15	Organization for standardization and certification of materials and packaging	Branch Manager and Manager Bioproducts Certification	private	foreign
16	Organization for certification of materials and packaging	Research expert	private	national and foreign
17	Organization for standardization	Vice president	public	national
18	Waste management entity	Director of the Environmental Protection Department	private	national
19	Waste management entity	Energy Director	private	national
20	Waste management entity	Technology manager	private	national
21	Public administration institution	Environmental Development Specialist; Director of the Municipal Economy Department	public	national
22	Public administration institution	Director of the Waste Management Department	public	national
23	Public administration institution	Head of the Department of Adaptation to Climate Change	public	national
24	Non-governmental entity	General Director	non-profit	national
25	Non-governmental entity	President	non-profit	national
26	Non-governmental entity	President	non-profit	national
27	Non-governmental entity	Chairman of the Board	non-profit	national
28	Scientific and research institution	Professor	public	national
29	Scientific and research institution	Director of the Institute	public	national

Source: own study.