State of the art and future scenarios for bio-packaging market transition: evidence from Poland

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Abstract

Purpose – The purpose of this article is twofold. First, this study characterises the current state of the bio-packaging market's development. Second, it identifies key factors influencing and possible scenarios of the bio-packaging market transition to increase the market share of compostable packaging.

Design/methodology/approach – The results of 29 in-depth interviews (IDIs) with representatives of the key groups of bio-packaging supply chains' (SCs') stakeholders were the input for the consideration of the research problem.

Findings – The main economic, legal, social and technological enablers and barriers to the bio-packaging regime transition are recognised, and their impact at the market level is explained. The authors recognised the hybrid transition scenario towards an increase in the market share of compostable packaging related to the three traditional pathways of transformation, reconfiguration and technological substitution.

Originality/value – This study contributes to a better understanding of the socio-technical system theory by examining interdependencies between landscape (external environment), market regime (bio-packaging market) and niche innovations (compostable packaging) as well as system transition pathways. The findings and conclusions on bio-packaging market developments can be important lessons learnt to be applied in different countries due to the same current development stage of the compostable packaging lifecycle worldwide.

Keywords Packaging, Bio-packaging, Compostable packaging, Market transition, Stakeholder, Environmental responsibility

Paper type Research paper

1. Introduction

The global food packaging market is developing at a dynamic pace, considering its size, value trends and innovations. The market size was USD 338.34bn in 2021 is projected to grow to 478.18 billion in 2028 at the compound annual growth rate (CAGR) of 5.1% during the 2021–2028 period (Fortune Business Insight, 2022). The circular economy (CE) principles, particularly regarding the lifecycle of packaging have gained an increasingly important role in the sustainable development of the packaging market (Mordor Intelligence, 2021). Along with the need to ensure circularity, packaging as a product is gradually evolving, depending on the type of resources used and biodegradability of the material. European Bioplastics

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divides materials into four categories: (1) non-biodegradable, fossil-based conventional plastics; (2) biodegradable, fossil-based bioplastics; (3) non-biodegradable, bio-based bioplastics and (4) biodegradable, bio-based bioplastics (European Bioplastics, 2021). The segment of bio-based and biodegradable materials has attracted the most attention for environmental reasons (Sapuan and Ilyas, 2021). The term bio-packaging refers to packaging made of bio-based (derived from renewable resources) materials suitable for biodegradation (Ciechańska, 2019). As a relatively recently emerging industry, the bio-packaging sector has strengthened its importance in the food packaging market.

The aim of this article is to outline the current state of the bio-packaging market development and to identify key factors influencing and possible scenarios of its transition towards increasing the market share of compostable packaging. The authors conducted their considerations through the lens of socio-technical system theory. Their study is based on evidence from Poland, a member state of the European Union (EU). It addresses the need to investigate potential and applications of bio-based, biodegradable and compostable packaging in a systemic approach. So far, only few research studies on the bio-packaging market have been published, directing most attention to the emerging sector of compostable packaging. The EU adopted a policy framework on the sourcing, labelling and use of bio-based plastics and the use of biodegradable and compostable plastics in 2022, but there is currently no EU law dedicated to bio-packaging specificity. As European Bioplastics (2022) reports, some EU legislation (EU Taxonomy, the Single-Use Plastics Directive, the Plastic Carrier Bags Directive, the Packaging and Packaging Waste Directive as well as the Waste Framework Directive) addresses some aspects and applications of bio-based, biodegradable and compostable plastics.

We contribute to research on market transitions phenomenon in several important ways. First, we extend the literature on the empirical qualitative exploitation of the socio-technical theory, unravelling factors affecting the transition pathways and exploring the significance of emerging niche innovations. Second, by identifying possible scenarios of the bio-packaging market transition to increase the market share of compostable packaging, we add value to a deeper understanding of the particular transition pathways and reveal the need to explore hybrid approach in research studies on transitions of contemporary markets. We also advance knowledge about conditions for the successful exploitation of niche innovations for a new market regime prosperity. Finally, we provide new important practical insights for stakeholders opening the window of opportunities hidden in the compostable packaging potential in the light of CE, but so far rarely exploited on packaging markets.

This paper is organised as follows. Section 2 provides a theoretical background regarding the essence of socio-technical system development, making an attempt to define and explain its elements from a multi-level perspective (MLP). Section 3 presents the materials and methods used in this study. Section 4 focusses on the research results to investigate the specificity of the bio-packaging socio-technical regime, key trends in its landscape and the role of the compostable packaging niche. In Section 5, we discuss the findings and their implications for the potential transition of the bio-packaging market. Section 6 presents the main conclusions, key research implications and limitations and future research directions.

2. Theoretical background

The problem of plastic waste is widely presented in the world's scientific literature. It is emphasised that the use of plastic materials leads to waste accumulation, greenhouse gas emissions, pollution of the marine environment and soil destruction (Chu *et al.*, 2022; Meys *et al.*, 2021). This occurs in problems such as climate change and resource depletion, which have prompted reflection on the CE (Gallego-Schmid *et al.*, 2020; Durán-Romero *et al.*, 2020; Barnabè and Nazir, 2022). The transition to a circular and bio-based economy is being

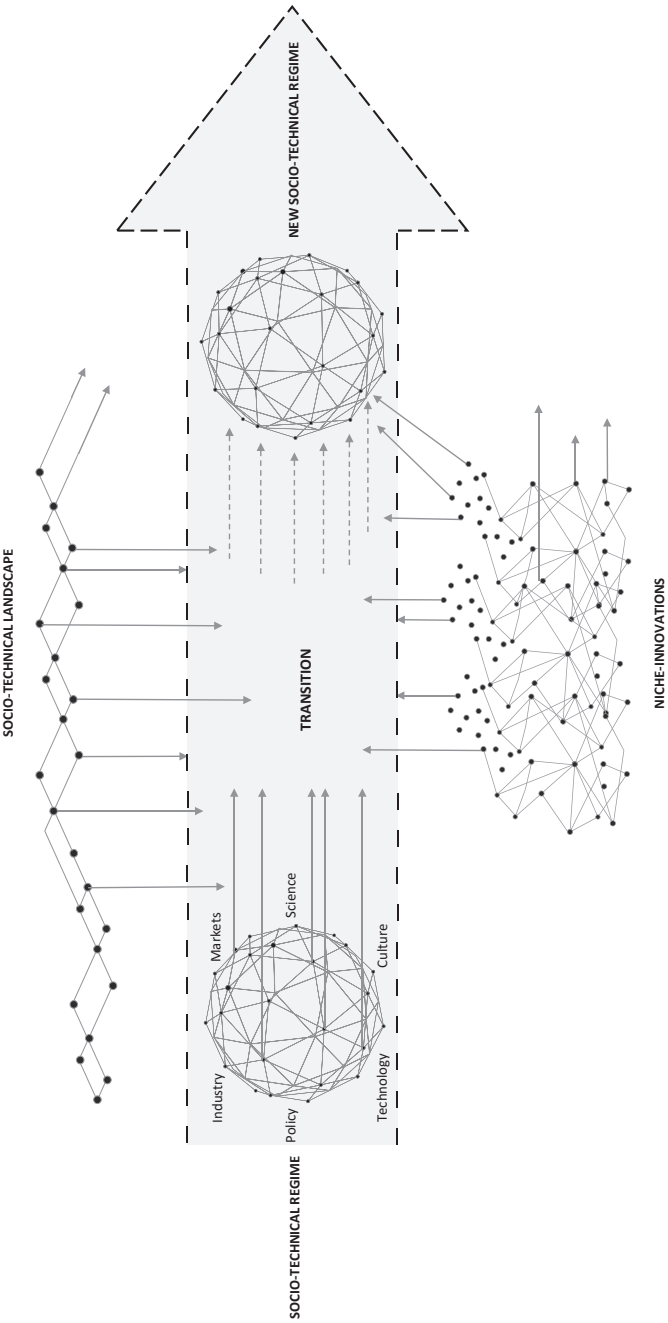
encouraged by policy-makers (Hamed *et al.*, 2022). The EU has undertaken an action plan to maximise the usefulness of resources and materials in the economy for as long as possible whilst minimising waste. It assumes that the transition to a CE will provide a competitive advantage for the European market, making it independent of limited resources (Matthews *et al.*, 2021). A significant change could come from replacing plastic packaging with biodegradable ones. However, commercialisation of bio-packaging on a large-scale remains challenging, conventional plastics have a well-established and mature technology for production and management (Filiciotto and Rothenberg, 2021). Even in the best scenario and with vigorous management, plastic pollution will increase in the coming decades (Galati and Scalenghe, 2021; Borrelle *et al.*, 2020). These challenges lead to changes in socio-technical systems and create new perspectives for sustainability transitions, which address issues like natural resources depletion, increasing global food demand and climate change with the goal of developing new, low emission, resource-efficient and sustainable materials (Ravindran and Jaiswal, 2016).

Socio-technical systems consist of various networks connecting actors, institutions, material artefacts and knowledge (Geels, 2004; Markard, 2011; Weber, 2003). Entities of the system have own interests, problem perceptions, values, preferences, strategies and resources, tightly interrelated and dependent on each other (Finger *et al.*, 2005; Geels, 2005). Processes that lead to fundamental systems shifts are socio-technical transitions. These are the transfers from one socio-technical regime to another, which, according to the MLP, occur through a combination of (macro) landscape pressures and (micro) niche development (Geels and Schot, 2007). Thus, the MLP model is a framework for understanding transitions that provides an overall view of the multi-dimensional complexity of changes in socio-technical systems (Geels, 2010). Due to its comprehensiveness, the MLP framework is widely used in recent research on areas such as: sustainability transitions (Vähäkari *et al.*, 2020; Keller *et al.*, 2022), digital technologies for the CE (Trevisan *et al.*, 2023), municipal solid waste management (Iyamu *et al.*, 2022), energy transition (Prados *et al.*, 2021), food processing (Gruchmann *et al.*, 2021) and plastic waste prevention, reuse and recycling (Oyake-Ombis *et al.*, 2015). The MLP concept provides a valuable instrument to analyse the empowerment of the bioplastics technological niche (Smith and Raven, 2012) towards bio-based economy and food plastic packaging transition towards circular bioeconomy (Beltran *et al.*, 2021).

The landscape is the broadest context considered in the MLP model (Figure 1). It refers to the macro-level aspects that occur in the external environment and influence socio-technical system development (Geels, 2005). The landscape includes trends related to the context of social behaviour, cultural patterns, demographic change, system disruption and macro-political issues (Barbanente and Grassini, 2022). As a consequence of changes in the external environment, the landscape exerts long-term and slowly progressive pressure on the regime, contributing to system transition.

The socio-technical regime is concerned with the rigid framework and stability of structures within the system. Regime is formulated by engineering practices, routines and the dominant technologies linked together (Geels and Schot, 2007; Geels and Kemp, 2007). It is co-created by society, scientists, policy-makers and other groups (Morgunova, 2021). This is enabled by formal and informal rules – which include shared beliefs and values, routines, regulations, institutionalised practices and capabilities – that influence each other and are generated by actors (Geels, 2004, 2011). The most widely used MLP model in the literature (Geels, 2002), captures six interlocking dimensions of the regime: markets (user preferences), science, industry, policy, technology and culture not eager to change and possessing a certain resistance (Geels *et al.*, 2017a, b).

If the regime is destabilised, either internally or through landscape pressure, niche innovations can overcome such resistance. This part of the system includes entrepreneurs, start-ups, activists and pioneers seeking to scale up innovative activities (Geels, 2019). Niche



Source(s): Figure by authors, based on Geels (2011)

Figure 1.
Framework for the socio-technical transition

is a narrow area for collaboration and innovation creation that benefits from and improves technological development. Niche can become a catalyst for regime change by taking advantage of "windows of opportunity" and initiating system transition.

In the MLP transition typology, there are four transition pathways characterised in terms of the nature and timing of the interactions amongst the landscape, regime and niche levels. The *transformation* pathway is triggered by changes in the external environment. The moderate influence of the landscape on regime actors leads to slow changes in the regime structure. If landscape changes create strong and sudden pressures, the regime experiences high tensions. *The de-alignment and re-alignment* paths assume that, as a result, regime actors experience internal problems leading to destabilisation. This is a chance for niches to exploit a "window of opportunity". If they are underdeveloped at this stage, the regime's problems become an occasion for accelerated development. However, if niches are adequately developed and have mature innovative nature, a technological pathway is possible. It assumes *technological substitution* with strong landscape pressure and niche willingness to break the regime. The readiness of niches without pressure from external actors is insufficient to make a change. The regime notices niches but does not feel the pressure of the landscape and assumes that it can provide the appropriate level of technological innovation on its own. The scenario in which the solutions that emerge in niches are slowly implemented in the regime is the *reconfiguration* pathway. If the effects of adaptation are perceived favourably by the regime, slow changes will occur internally. This is a purely economic solution which leaves most regime rules unchanged.

3. Methodology

This study is part of a three-year international project that focusses on the issues of bio-packaging in the food industry. Partners from two European countries, one from the North America and one from the South America–are involved in the project. This article demonstrates the research results collected in Poland, one of the EU countries.

As the bio-packaging market in Poland is young, participants in this market constitute a relatively small group. Therefore, an in-depth interview (IDI) was the most appropriate method to obtain a variety of results from key stakeholders in packaging supply chains (SCs). The use of the qualitative method allowed to capture details relevant to the changes taking place in the regime under the influence of specific factors. It should be emphasised, that the selected group of interviewees is very aware of environmental problems, which ensures the acquisition of comprehensive knowledge about the studied topic. The adopted research perspective was the multi-actor network approach in the context of the socio-technical theory.

First, a database of participants operating in the bio-packaging market for food was created. The adopted criteria for selecting study participants were as follows. Firstly, the functioning at the Polish food bio-packaging market, and secondly, representing an internal or external stakeholder of food bio-packaging SCs. Having compiled a list of various stakeholders, individual letters of intent containing invitations to the study were sent out. Consequently, the following groups of market participants were included in this study:

(1) Suppliers of raw materials and bioplastics (one IDI);

(2) Packaging manufacturers (five IDIs);

(3) Packaging distributors (five IDIs);

(4) Individual clients – consumers (two IDIs);

(5) Organisations for standardisation and certification of materials and packaging (three IDIs);

(6) Waste management entities (three IDIs);

(7) Gardening company (one IDI);

(8) Public administration institutions at the central and local levels (three IDIs);

(9) Non-governmental entities (four IDIs);

(10) Scientific and research institutions (two IDIs).

Appropriate research was conducted between September 2020 and April 2021. The study was possible thanks to the openness and commitment of the top management of the organisations, and it took place during two dedicated meetings (Figure 2).

The first meeting was the informative one. The research team presented the research assumptions and stakeholder representatives described their activities l. The second meeting included IDI aimed at diagnosing the landscape, bio-packaging market and compostable packaging niches. It took approximately 60–90 min. Consequently, 29 IDIs were conducted. The respondents were mainly owners and managers of companies, directors of public institutions and presidents of associations.

For each interview, the research team prepared a unique set of open-ended questions. They were all aimed at recognising the main determinants of the development of the bio-packaging market and in particular the importance and potential of compostable food packaging for future transformations of this market. This direction of research was determined by the results of a systematic literature review on compostable packaging SCs (Brzeziński *et al.*, 2021) as well as the analysis of the literature on market transition (e.g.: Geels *et al.*, 2017a, b; Morgunova, 2021). Depending on the role of the market participant (e.g.: manufacturer, distributor) and the sector in which the respondent operates (public, private, non-profit), the in-depth questions during the interview were slightly adjusted, if there was a need. However, the researchers when conducting the interviews carefully kept the research regime. They used the same main questions to maintain the direction and the integrity of the qualitative study. The examples of key questions are as follows:

(1) What are the key external and internal factors influencing the development of the bio-packaging market?

(2) What are the enablers and barriers to the development of the compostable packaging market?

(3) How do you assess the potential and directions of the development of the compostable food packaging market?

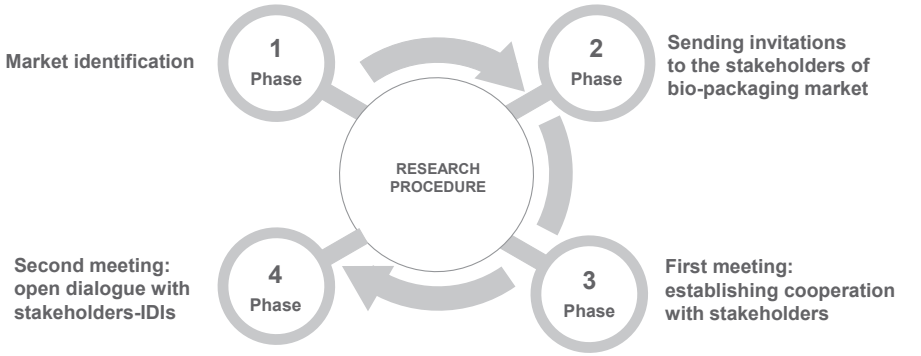


Figure 2.
Research procedure

Source(s): Figure by authors

(4) How do you assess the current and the future changes in the bio-packaging market influenced by the development of the compostable food packaging niche?

(5) What conditions must be met to increase the market share of compostable packaging and transform the bio-packaging market?

Each interview was transcribed. All collected data were analysed for various variables in the multi-dimensional system. The variables that were the input elements for the analysis of the obtained data were mainly determined by the socio-technical theory. Thus, they covered political, economical, social, technological, legal, environmental (PESTLE) factors, market factors [e.g. price, demand, business-to-business (B2B) relationships and competition] and eco-product innovations in the compostable food packaging niche.

4. Results

4.1 Socio-technical landscape

The socio-technical landscape is a broad perspective that changes the system by shaping its elements according to trends and external factors, referring to the PESTLE analysis of political, economic, social, technological, legal and environmental areas (Basu, 2004). Regarding bio-packaging systems, prominent trends are related to environmental issues. The nature of the socio-technical landscape is a result of increasing environmental pollution and uncontrolled use of natural resources. These two factors have contributed to trends such as political and consumer demands for corporate social and environmental responsibility (CSER), increased consumer awareness of resource wastage and sustainability orientation.

These trends are reflected in climate policies incorporated into global and regional contexts. Sustainable development strategies and guidelines aim to reduce climate change and draw the attention of consumers and businesses to the threats caused by irresponsible production and consumption. These policies can, on the one hand, promote and appreciate beneficial actions, but, on the other hand, can also be a barrier for companies that do not consider the environment in their activities. Although the scene is changing and businesses recognise burning issues on a global level, the shifts that have already taken place in the environment are often irreversible. The concept of CSER being increasingly expressed in business activities is to provide a balance between ensuring a safe profit and social and environmental aspects in the activities of enterprises. Although companies often choose to take this direction, both consumers and policy-makers strongly demand this approach.

The growing awareness of resource waste is related to corporate social responsibility and reflects concern for the environment in the production of goods and their packaging. The sourcing of raw materials, production technology and distribution conditions can lead to waste of resources. Consumers are becoming increasingly aware of this fact by observing the extent to which plastics are used in the packaging market. Consumers' growing awareness of the environmental impact of plastics has led to public opposition. Images of various regions, in which the environment has been littered with single-use packaging have become part of a culture of rebellion against the practice of using this type of material. Although this trend is still developing, its effects can be observed, for example, by avoiding single-use packaging, thereby creating space for biodegradable packaging.

A broader view of the changes that occur in the environment has led to the sustainable development. This idea not only considers the current state of the environment but also the well-being of future generations. The highlighted changes taking place in the landscape are reflected in the sustainable development goals (SDGs), especially in terms of Goal 12 (responsible consumption and production) and Goal 13 (climate action).

4.2 Socio-technical regime

According to the Polish Chamber of Packaging (2019, p. 3), the market for biodegradable packaging has the value of EUR 10.4 billion and accounts for app. 2% of the Polish packaging market. *The regime* of the bio-packaging market is created by stakeholder groups that can be divided into internal and external stakeholders of bio-packaging SCs. The group of internal stakeholders include suppliers of raw materials and bioplastics, packaging manufacturers and distributors, business clients, individual clients (customers) and waste management entities. Nowadays, price is the most important factor contributing to the competitiveness of bio-packaging. There have also been gradual changes to increase the importance of sustainable competitive criteria. The above-mentioned entities are very diverse in terms of the size, scale and level of advancement of their activities, which hinders their integration and cooperation for market value co-creation. Transactional relationships and formal contractual rules dominate market players' activities. The scale and scope of cooperation between internal stakeholders in value co-creation initiatives, such as in the design and commercialisation of bio-packaging, sharing of production capabilities and outsourcing, are still very limited. Strong market competition, lack of trust and fear of losing intellectual property are significant features of relationships between the regime's participants. Relationships between internal stakeholders are fragmented and still insufficient for the configuration of an integrated value system in line with the CE principles and close bio-packaging lifecycle in the most environmentally friendly way. On the one hand, international fast moving consumer goods (FMCG) corporations and retailers develop business strategies and practices for CSER. Trend-setters develop cross-sector partnerships based on shared values and a vision of circular SC management. The Polish Plastic Pact is a good example of such a collaboration between FMCG market leaders united around the United Nation (UN) SDG. On the other hand, start-ups as newcomers, established by representatives of the Y and Z generations, build responsible business models aiming at the development of eco-innovations.

Moreover, a variety of products are offered on the Polish bio-packaging market in terms of ecological characteristics, including biodegradability. Due to the relatively low average level of corporate environmental responsibility and awareness, greenwashing is one of the routines in the regime. This practice is generated by individual actors and affects others. Amongst internal stakeholders, there are entities that practice greenwashing intentionally and consciously as well as those that use it unintentionally and unconsciously. Neither normative rules nor common beliefs eliminate unethical entities from the market. Therefore, there is a strong need to develop institutionalised formal rules for bio-packaging standards as well as bio-packaging waste codes. The standardisation process will be helpful for managing waste streams in more efficient way and increasing circularity of bio-packaging and biomaterials in the economy.

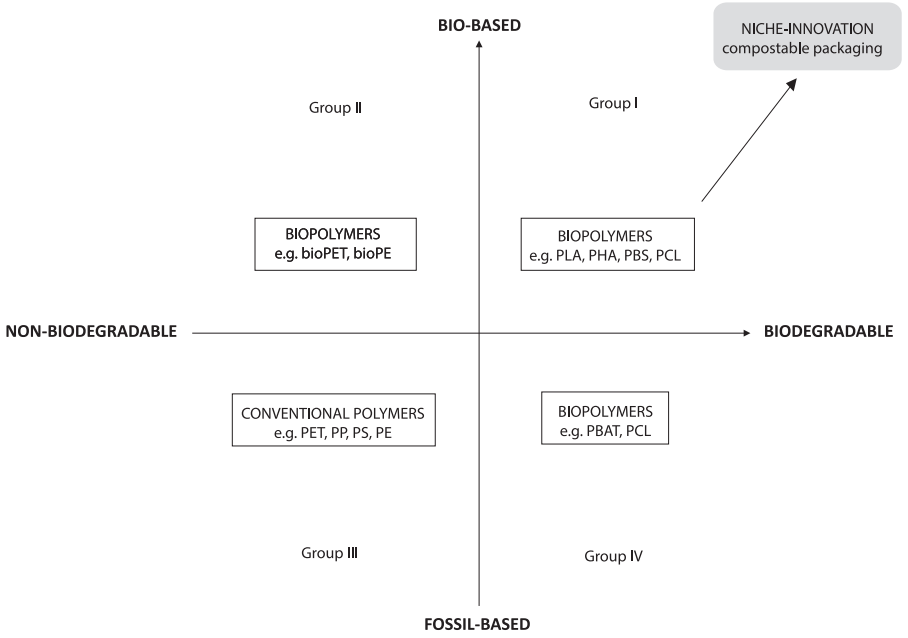
The bio-packaging regime is co-created by customers buying bio-packed, fast-moving goods, including food products. The general tendency is a gradually growing interest of consumers in both the type and quality of packaging, but they still do not have sufficient knowledge of the bio-packaging features. However, an increasing demand for bio-packaging in the B2B and business-to-consumer (B2C) markets can contribute to greater regime stability and continuous development in the near future. Although there are rules guiding the activities of regime actors, there are problems with the appropriate quality of packaging waste segregation and scale of bio-packaging recycling in line with the CE principles.

The group of external stakeholders includes public administration institutions, non-governmental entities, standardisation and certification organisations for materials and packaging, scientific and research institutions. The group of external stakeholders is not systematically integrated for the benefit of CE. Public institutions at the central level play an important role in many areas, creating conditions for regime development in light of the CE principles and formally affecting other stakeholder groups. They participate in the policy arrangements of the EU, design national strategies for sustainable socio-economic development, create legal regulations and implement acts. However, there is still no national CE strategy and

regulations supporting the stable development of the described regime or investment policy introducing incentives for the entrepreneurship of business and individual stakeholders. Local government entities formally implement central regulations at regional and local levels. The research results highlighted that routines, capabilities and institutionalised practices are diverse across the country. The lack of coherence and transparency in regulations is an important obstacle to achieving stability in the bio-packaging regime. Business unions, associations, or clusters are important stakeholders formally participating in public consultations of legal acts at the national and EU levels. They also play a significant role in educating entrepreneurs about the CE principles and changes needed in business models. Furthermore, they develop consulting services that support entrepreneurs' acquisition of financing and implementation of investments. It should be noted that the collaboration of associations or cluster members is primarily of a traditional nature through direct contact, conferences, projects and working groups. Rather, they do not develop modern digital platforms to better manage relationships and achieve synergy effects. However, they collaborate on an international scale, for example, within the associations of European Bioplastics and European Plastics Converters. Non-government organisations play a similar educational role by promoting and disseminating information on circularity. Scientific and research institutions conduct projects aimed at developing new materials for bio-packaging. They obtain patents to protect their intellectual property in light of patent law. The research findings reveal high barriers to innovation commercialisation in the Polish market. Cooperation between research institutes and enterprises of various sizes, including start-ups, is an emerging trend in both public and private spheres.

4.3 Niche innovations

There are four main groups of polymers (European Bioplastics, 2018). In the last few decades, the most popular packaging materials have been non-biodegradable polymers of petrochemical origin (Figure 3, Group III). Conventional plastics of this type are mainly



Source(s): Figure by authors on the base of European Bioplastics (2018)

Figure 3.
Niche innovation in the light of four groups of polymers

obtained from polymers such as polyethylene terephthalate (PET) or polypropylene, *inter alia*, for the production of bottles, take-away packaging and foil food packaging. However, in light of the growing problem of plastic waste contamination (mainly salt water) and the strict legal regulations (e.g.: the waste package adopted in the EU), companies are increasingly interested in the development of innovative polymers and eco-design.

As conventional plastics produced today on a mass scale are a very serious source of environmental problems and consequently have a negative impact on human health, bio-based and biodegradable plastics are becoming the most ecologically friendly alternative. Simultaneously, compostable packaging has emerged, constituting an important *niche innovation* in the bio-packaging market in Poland (Figure 3, Group I).

Compostable packaging meets the requirements of the European standard EN 13432:2000 (European Committee for Standardization, 2000), which is in accordance with the European Directive on Packaging and Packaging Waste (94/62/EC). In Poland, an increasing number of companies are interested in this type of certification to ensure the credibility of products, especially in light of the greenwashing. Moreover, certified packaging increases competitiveness in both the national and international bio-packaging markets. The requirements of this standard concern include heavy metal content, biodegradability and fragmentation. If packaging consists of several packaging materials, each should be tested and adequately characterised. Compostable packaging is packaging that will biodegrade to at least 90% within six months. It is crucial that the aerobic composting process leads to the formation of naturally occurring compounds in the natural environment, such as water, carbon dioxide and biomass (Sikorska *et al.*, 2019). The certification process integrates SC links, as each company is responsible for the conformity of its product, such as raw material, component, constituent, or final product. In Poland, the main domestic source of raw materials for the production of compostable packaging is waste from the food industry, such as cereal bran or fruit marc. Suppliers of more advanced and certified materials [bioplastics based on cellulose and bioplastics based on polylactide (PLA) polyhydroxy alkoxide (PHA)] are located abroad. The study shows that the largest group of SC stakeholders involved in the packaging certification process in Poland are producers of compostable film (including laminates) and producers of compostable packaging. These are mainly start-ups and domestic (or foreign) companies specialising in the production of packaging and, owing to the emergence of new eco-innovations, launching new production lines for compostable goods. In recent years, Polish distributors have also emerged who trade imported compostable packaging, especially in the catering industry.

4.4 Enablers and barriers for the food bio-packaging system transition

Qualitative research has allowed for the identification of factors influencing the development and changes in food bio-packaging system towards circularity (Table 1). The list includes

Determinant	Function
Innovation development	enabler
Environmental education of society	enabler
Waste management infrastructure	enabler
Legal regulation and standards	enabler/barrier
Corporate environmental responsibility	enabler/barrier
Bio-packaging properties	barrier
Economic conditions	barrier
Industrial infrastructure	barrier
Social conditions	barrier

Source(s): Authors' own study

Table 1. Determinants of food bio-packaging system transition

both the drivers and inhibitors that influence this transition. Some of these factors may serve both functions and their ultimate dimensions depend on the balance of power in the landscape, regime and niche.

The first stimulating factor is the creation and implementation of innovations, such as product (e.g.: compostable packaging), processes (e.g.: packaging eco-design processes), technological (e.g.: adaptation of production lines to handle bio-packaging) and organisational (e.g.: industry association platforms and clusters), which determine the development of a food bio-packaging system.

The next determinant of the socio-technical system transition is education to increase social environmental responsibility and promote the benefits of separate collection and organic recycling of compostable packaging. "There is a huge need for education on how to distinguish these (compostable) packaging" (Interview 10). "It is worth starting education from school" (Interview 13). However, it has to be strengthened by the development of waste management infrastructure and the introduction of mechanisms for bio-waste management.

The key to supporting the development of food bio-packaging SCs is macro-environment perspective, especially new and more effective legal regulations facilitating the production and distribution of compostable packaging. "The lack of uniform regulations and standards binding packaging manufacturers encourages abuse on the part of companies" (Interview 13). Simultaneously, non-obligatory initiatives are also important, such as the development of standards that unify the compostable packaging lifecycle management based on circular principles. Reliable certification increases the transparency of information and reduces greenwashing. "Certification may take from several weeks to several months" (Interview 5). "However, this (90 days for composting) is a very long time. There is a need to reduce this time to 3–6 weeks and to accept it in every country" (Interview 5). "We proposed to declare compliance with standards, not require a certificate" (Interview 1).

Legal regulations, indicated as enablers, are simultaneously an element that hinders the development of the system. The main issue is the lack of coherent and transparent legal regulations to effectively support the development of CE economy and systemic solutions in Poland. The lack of efficiency in translating strategies, policies and provisions of the EU documents into national legislation is noticeable. There is a need to provide incentives for plastic manufacturers to effectively implement the principles of the CE economy or restructure operations in order to shift to the production of bio-packaging.

The barrier to the socio-technical system transition is the property of compostable packaging. Limitations arise from their utility compared to the properties of conventional plastic packaging, which have advantages in ensuring the quality and safety of food products. In addition, the market lacks unified methods for labelling compostable packaging. "The barrier for CE is labeling" (Interview 2). "It would be appropriate to introduce markings allowing for easy and universal recognition of the ecological class of the packaging (Interview 5)". "The traceability of the packaging is also an issue" (Interview 28). There are also no clear rules on how it should be managed after use to ensure that it is closed in the most desirable manner for the environment. Another debatable aspect related to the lifecycle of bio-based packaging is the environmental impact of its production, which is often overlooked by producers.

Another factor hampering the transition of the socio-technical system is the economic conditions reflected directly in the high market prices of bio-based packaging, which are not competitive with other types of food packaging. They are the result of high process costs in SCs (resulting from R&D expenditures, the lack of availability of raw materials in the domestic market, the limited scale of industrial production), difficulties in production and distribution logistics and the need to obtain certificates and integrate certification amongst

participants in SCs. "There is a lack of financing of R&D activities on the bio-packaging market by the state" (Interview 10). "Certification would limit us to cooperation with one supplier of granulate, because we would certify our packaging from this granulate" (Interview 1). The socio-technical system also includes infrastructural elements. "The key stakeholder of the closed cycle of compostable packaging are local governments, which determine the infrastructure and effective waste segregation, including bioplastic packaging" (Interview 3). A barrier preventing the shift towards circularity is the lack of adequately developed infrastructure to segregate and process packaging waste on an industrial scale. Access to infrastructure is one of the reasons why waste is not received with sufficient quality, which in turn prevents closure of the lifecycle of the compostable packaging by producing compost for use in agriculture or horticulture. 'Systemic solutions for the collection and recycling of bio and compostable materials are not widespread and there is a large gap, especially in terms of infrastructure for processing compostable materials. "The sorting system in Poland and in Europe is not prepared for proper sorting and processing waste from compostable packaging" (Interview 5).

Other identified barriers arise from social background. They concern consumer awareness, knowledge, attitudes and behaviours, which are insufficient for the implementation of CE principles. "The consumer is the weakest link in the CE (of packaging)" (Interview 28). There has been a regular increase in the environmental responsibility of consumers, which is a source of demand and market driving force. At the same time, however, the environmental properties of packaging are rarely a criterion for the choice of food products because bio-packaging is usually poorly labelled and associated with higher food prices.

5. Discussion

A particularly important future perspective for the transformation of the bio-packaging regime is the creation of a system based on the CE principles, for which both an integrated approach and a holistic perspective are desirable. The application of the CE concept is strongly determined by developing legal regulations and implementing acts at the level of both central and local government administrations. In the case of the EU members also regulations at the international level can play an essential role because of their transferability. These findings confirm that the transformation of the bio-packaging regime towards circularity can be driven by legislation and are consistent with the conclusions of other authors, emphasising the need to incorporate the principles of the CE into public policies, legal instruments and fundamental changes in the law (Oliveira, 2020; Zarbà *et al.*, 2021). Several normative documents have been developed to support product lifecycle management in accordance with the CE principles, as well as to reduce the amount of conventional packaging: *A European Strategy for Plastics in a Circular Economy* (European Commission, 2018), *New Circular Economy Action Plan* (European Commission, 2020), Directive 2019/904, Directive 2018/851, Directive 94/62/EC, extended producer responsibility (EPR) Policy. European legal acts must be transposed into the national legislation of the EU members. As the research findings prove, factors contributing to niche development are the transparency and coherence of regulations and executive acts between all levels of legislation. Relevant legal regulations and actions at the municipal level play an extremely important role (Trubetskaya *et al.*, 2022). However, there is no state strategy for developing the compostable packaging market in Poland, similarly as in other EU member countries nowadays.

The next pillar of the transformation of the bio-packaging regime is stakeholder education, especially in the CE field (Bugallo-Rodríguez and Vega-Marcote, 2020; Serrano-Bedia and Perez-Perez, 2022). Its significance is perceived as a remedy for greenwashing (Fernandes *et al.*, 2020; Rosenboom *et al.*, 2022). The awareness and activities of stakeholders should evolve towards

increasing environmental responsibility. The research findings revealed that managers are often unaware of the advantages of developing circular business models or perceive the related risks as too high to implement them. Sustainable entrepreneurship in the bio-packaging market can be effectively stimulated through educational, informational and promotional campaigns. This is also confirmed by other studies referring to the need to make stakeholders aware of sustainable change (Gruchmann *et al.*, 2021). Moreover, the enhancement of consumer awareness, knowledge and behaviour may impact the development of the bio-packaging regime on the demand side. It is also a prerequisite for closing the bio-packaging lifecycle in the most environmentally friendly manner, as it determines consumer involvement in the waste segregation. Responsible segregation of bio-waste essentially depends on the proper labelling of packaging or the information on it. According to Taufik *et al.* (2020), greater consumer familiarity with bio-based products is positively related to adequate disposal of bio-based plastic packages.

Growing consumer awareness is increasingly reflected in the Polish market. Clients' ecological awareness translates into an increased demand for compostable packaging and, consequently, into greater supply and economies of scale obtained by production and distribution companies. Such an effect may reduce the price of packaging and thus increase the competitiveness of certified compostable packaging compared to other types of bio-packaging. In Poland, awareness and behaviour amongst consumers towards ecological products, including food packaging, are improving (Cynk, 2017; Cichocka *et al.*, 2020). This is partly due to wider public education on environmental issues. The plethora of campaigns provided by governments and NGOs has intensified social interests in sustainability. The ongoing public debate on the CE and natural resource management explains the importance of these issues and increases the environmental awareness (Didham and Ofei-Manu, 2020). Consumers pay more attention to the quality of the environment and begin to care about the environmental characteristics of a product, such as eco-friendly raw materials and recycling (Zhang *et al.*, 2019). Researchers have investigated the effects of environmental awareness on purchasing environmentally friendly products (Wang and Hazen, 2016). The environmental attitude has a positive impact on the purchasing decision-making process (Xu *et al.*, 2018; Wang and Hazen, 2016). Both consumers and businesses are making increasingly conscious efforts to become environmentally aware, and the market for these types of products is growing (Zhang *et al.*, 2015). Consumer awareness is an important factor in the purchase decision-making process, but on the other hand, an essential barrier is the purchasing power of society. Economic factors have been proven to sustain eco-responsible behaviour (Rustam *et al.*, 2020).

The research results revealed the importance of innovation development for the transformation of the bio-packaging regime. Different innovations can influence the product portfolio available on the bio-packaging market and the reconfiguration of structures, integration of processes and advancement of relationships between stakeholders of bio-packaging SCs. Bioplastic innovation has been at its highest level for almost two decades, and most patents are focused on biopolymer composition and structure (Bioplastics Magazine, 2021). On the one hand, Nanda *et al.* (2022) indicated their advantages over conventional plastics: "biodegradability, low carbon footprint, energy efficiency, versatility, unique mechanical and thermal characteristics, and societal acceptance". On the other hand, trade-offs should be mentioned: "negative agricultural impacts, competition with food production, unclear end-of-life management, and higher costs" (Rosenboom *et al.*, 2022).

The creation of the compostable packaging market was made possible by innovations, especially in the field of obtaining biopolymers from plant raw materials, such as PLA and PHA (Šprajcar *et al.*, 2012, pp. 19–20; Marra *et al.*, 2016; Genovese *et al.*, 2017), paper-based materials (Coles, 2013), edible films and coatings from food residues (Gaspar and Braga, 2023), films from starch corn (Giuggioli *et al.*, 2017) and fibre waste (Aluigi *et al.*, 2008). These

materials offer an opportunity to use organic recycling for compostable packaging. Packaging improvements and technical innovations represent significant opportunities to reduce food waste (Verghese *et al.*, 2015). Creating and implementing innovations as a result of R&D and technological progress should also be aimed at introducing new biopolymers (Otoni *et al.*, 2021), continuously improving their properties and increasing the usefulness of compostable packaging. Biopolymers can have properties similar to conventional plastics (Bukowska-Śluz, 2004; Foltynowicz and Jakubiak 2002; Šprajcar *et al.*, 2012, p. 20). Still, these properties are not sufficient for some eco-innovations, taking into account ensuring long shelf life, dealing with a high temperature or with liquids released by food (Yuvaraj *et al.*, 2021). It is worth adding that the challenge is to develop compostable packaging that will ensure the lowest possible level of environmental impact throughout the lifecycle. There is still discussion on whether bio-based materials are environmentally friendly options compared to plastics in terms of lifecycle assessment (Khoo *et al.*, 2010). Second, future transformation of the bio-packaging regime depends on the adaptation of technological innovations on an industrial scale. The importance of this condition was recognised in the field of production technology (Bezirhan Arikan *et al.*, 2021). The research results in Poland confirm the significance of production technologies, but also extend the scope of attention to technologies throughout the entire lifecycle of bio-packaging. In particular, it is worth highlighting the opportunities for the development of various types of materials and organic recycling technologies to close the bio-packaging lifecycle in modern waste management systems. Technological development of the new regime infrastructure can be perceived as a factor that accelerates process innovation.

The development of the compostable packaging market is supported by international and national standards such as EN 13432:2000 (European Committee for Standardization, 2000), ASTM D6400-4 (American Society for Testing and Materials/ASTM International) and ISO 17088 (International Organization for Standardization, 2021). Certification for compliance with their requirements ensures that the packaging decomposes into compost applicable in agriculture or horticulture and that the packaging is recognisable by product labelling. In this way, the use of standards increases the chance of a transition of the bio-packaging market towards circularity. A particularly important factor that increases the chance of niche development is the recognition of compostable packaging in relation to other packaging. For example, certification in accordance with the requirements of EN 13432:2000 allows for the use of a seedling logo. However, ensuring recognition is two-dimensional nature. On the one hand, it is necessary to properly label the compostable product; on the other hand, the client's knowledge of the message that this label provides is crucial. Therefore, a very important niche activator is educating B2B and B2C clients on the environmental friendliness of compostable packaging, as well as on the ability to recognise them properly. Proper labelling also provides a message during waste segregation, reducing the risk of unintentional contamination of the waste streams. The factor directly influencing this aspect is the ability of the packaging user to direct compostable packaging waste into the appropriate waste stream. In addition, a waste management infrastructure that meets the requirements of composting is particularly important. The lack of this infrastructure may have a negative impact on the possibility of using organic recycling, thus inhibiting composting processes and causing contamination of other waste streams (e.g. plastic waste), whilst not using the full potential of compostable packaging as a source of compost.

When assessing transition paths, it is difficult to choose one for Poland. Indeed, the different types coexist, interact with each other and, thanks to the synergy effect, influence changes in the development of the bio-packaging system. Similar doubts were highlighted by L. Kanger, who had difficulty adjusting the basic MLP pathways for energy transitions (the author proposed 16 different pathways for this area) (Kanger, 2021). In line with the *transformation path*, one can see the pressure of external factors on the niche and regime.

Legislative factors have been very much focussed on reducing environmental pollution, including plastic packaging waste and on implementing the CE principles. Technological changes are an important factor in the transition to sustainable bio-packaging management systems. *Technological substitution* has also been implemented in Poland owing to the pressure of the landscape. Various types of innovations appear, developed thanks to grants for new technologies in the area of material processing and compostable packaging production. They are often implemented as an effect of close cooperation between the scientific community and participants of the bio-packaging market.

As a result of the successive incorporation of niche compostable packaging into product portfolios of bio-packaging producers and its increasing implementation by suppliers, producers and distributors across different industries, the *reconfiguration pathway* is determined. Compostable packaging was initially adopted in pilot projects to test its features and potential in business and SCs. Its implementation triggers continuous adjustments in the basic architecture of the bio-packaging regime, especially in waste management systems, considering its participants, interdependencies between them and infrastructure. On one hand, it creates and enhances the chances of the development of organic recycling of packaging waste. On the other hand, it presents some threats, such as problems in its identification and contamination of waste streams. However, compostable packaging can be successfully adopted as a symbiotic innovation by various groups of bio-packaging regime stakeholders. Its adoption is driven mainly by environmental value, improving especially the environmental performance of businesses. Although the transition of the bio-packaging market is based on a *hybrid path* reflecting the characteristics of three theoretical approaches – *transformation, reconfiguration and technological substitution* – its character is rather evolutionary, not revolutionary in Poland. It does not reflect the *de-alignment path* or radical erosion of the bio-packaging regime.

6. Conclusions

Owing to the scale and growth dynamics of the global packaging market, its environmentally friendly transformation as well as the enhancement of social and environmental responsibility of stakeholders have become the most desirable and simultaneously the most outstanding challenges in the context of sustainable development and CE. The packaging waste problem is global in nature and requires systemic transformation. One of the most important contemporary trajectories is related to the emergence of the bioplastic packaging market and its future transitions. Considering the bio-based biodegradable packaging sector as a reference regime, the authors provide an in-depth analysis and explore transition scenarios towards increase the market share of compostable packaging.

The following theoretical and practical implications can be formulated. Firstly, the study enriches the research conducted so far on socio-technical system transitions. It shows that the regime transition can occur simultaneously along more than one transition pathway. The real-life transition pathway depends on many external (e.g.: economic and social conditions, legal regulations, technical standards) and internal factors (e.g.: development of industrial and waste management infrastructure, corporate environmental responsibility, environmental education, innovation and bio-packaging properties). Secondly, the research on socio-technical system transitions requires a qualitative approach in the multi-dimensional and multi-stakeholder perspectives. Third, it also provides new insights into empirical studies that consider the role of niche market developments, thereby to the knowledge in the field of management sciences. The study also has many practical implications. It considers bio-packaging market transitions and reveals trends of packaging market development. The "hybrid path" evidence from the

developing Polish bio-packaging market in the EU is an in-depth example that could be valuable lesson learnt for other national markets. The study characterises the transformation of the bio-packaging regime towards the emerging market of compostable packaging that could be a potential future scenario worth following by many countries. Furthermore, the study highlights potential roles and responsibilities of public and private decision makers depending on the transition pathways. Moreover, concerning the multi-stakeholder perspective, it sheds light on the types and influence of decisions of policy-makers shaping the landscape on the one hand and decisions of private investors and entrepreneurs regarding investment strategies and business models of companies offering bio-packaging and compostable packaging on the other hand, and finally, the purchasing decisions of customers. In this way, it reveals social impact of stakeholders of the bio-packaging market to stimulate changes towards the implementation of CE principles efficiently.

Although the authors are confident that the study has provided interesting and important results for the bio-packaging market transition, they are cautious that the research has a few limitations. The first-one may be the geographical coverage of the research limited to one country thereby providing country-specific findings. Simultaneously, it is worth emphasising that the current state of the bio-packaging market development is similar according to the need to define bio-packaging, implement rules of packaging design for the environment, CE or packaging waste management across many countries. Moreover, innovative compostable packaging is a niche innovation in many national markets and its market share is at a similar level worldwide. The second one may be the limitation of the research to key stakeholders. It will be desirable to carry out interviews with representatives of other stakeholder groups, which could ensure a complete picture of factors influencing the bio-packaging market transition (e.g.: manufacturers and distributors of products packed in bio-packaging and compostable packaging). Finally, the study was based on the qualitative opinions of respondents as usual at the early stage of a new research field exploration. Future research may be designed based on the mixed method approach, integrating qualitative and quantitative research methods.

Future research studies should include an investigation of further scenarios and paths of bio-packaging system transition. Second, it would be interesting to carry out in-depth comparative analyses of the current state of development and transition paths of bio-packaging systems in different countries at the level of macro- and micro-economic transformations. It should also be pointed out that the development compostable packaging market requires an appropriate framework. Therefore, special attention should be paid to designing a private-public system of tools and mechanisms that would best ensure the management of the lifecycle of compostable packaging in accordance with the CE principles.

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