European Research Studies Journal
Volume XXIV, Issue 4B, 2021

pp. 29-42

Barriers to the Development of Compostable Packaging in the Food Sector Against the Background of the Circular Economy: The Case of Poland

Submitted 17/09/21, 1st revision 22/10/21, 2nd revision 15/11/21, accepted 25/11/21

Łukasz Marzantowicz[1], Beata Wieteska-Rosiak[2]

Abstract:

Purpose: *The aim of the article is to identify the main barriers determining the low share of compostable food packaging in the circular economy in the country.*
Methodology: *The IDI - Individual In-depth Interview method was conducted among stakeholders of the supply chain of compostable packaging in the food sector. The private sector, public sector, users and the non-profit sector were studied.*
Findings: *From the obtained series of responses, those concerning the identification of barriers to the development of the compostable packaging market in the food sector were selected. Using the methods of induction and deduction, the catalog of these barriers was determined, the sources of their origin were indicated and their impact on the development of the market was shown. A particular focus for the analysis of the results was their reference to the postulates of the circular economy as the research background..*
Practical Implications: *The analysis of the research results provided knowledge and allowed to identify problem areas in the functioning of the compostable packaging market, supply chains and the circular economy, taking into account all stakeholders of the circular economy. Further directions of research and development in the presented problem were indicated.*
Originality/Value: *Original research.*

Keywords: *Compostable packaging, circular economy, food market, supply chain.*

JEL classification: *M21, L91, O20, Q01.*

Paper Type: *Research Paper.*

Acknowledgment: *This paper is an output of the science project "New Frontiers in Social Innovation Research: Social Innovation Management for Bioplastics", no. T-AP SI/SIMBIO/1/2020, financed by the National Centre for Research and Development (NCBR) in Poland, within the programme Trans-Atlantic Platform: Social Innovation Call.*

[1]*Department of Logistics, SGH Warsaw School of Economics,*
ORCID ID: 0000-0002-2887-2914, lukasz.marzantowicz@sgh.waw.pl
[2]*Faculty of Economics and Sociology, Department of Investment and Real Estate, University of Lodz, ORCID ID: 0000-0003-0353-2558, beata.wieteskarosiak@uni.lodz.pl*

1. Introduction

It has been known for a long time that social and economic development should be carried out in accordance with the principles of sustainable development. The necessity of global actions for sustainable development was emphasized in the document entitled "Transforming our world: the 2030 Agenda for Sustainable Development". The document adopted in 2015 by the countries of the United Nations presents 17 main goals of sustainable development. Among them, responsible consumption and production are promoted - based on the efficient use of natural resources (goal 12) and the prevention and reduction of the level of pollution of the seas and oceans, including plastics (goal 14) (United Nations, 2021).

The residual waste negatively affects the ecosystem and human health. Due to the high level of use and improper waste management, the oceans annually receive about 4.8-12.7 million tons of plastic, and currently there are as much as 150 million tons of them. Among them are plastic packaging, popularly used in the food sector (European Parliament, 2018). In the EU, packaging waste is the highest level of all plastic waste - as much as 58% (European Commission, 2018). Currently, they are discussed by the European Commission, which in order to solve the problems related to the ineffective economy of plastics and to pursue the goals of the 2030 Agenda, strongly promotes and implements the concept of the circular economy (CE) in its development policy.

The EU circular economy policy emphasizes the importance and development of alternative raw materials possible for the production of plastics, including those of a biodegradable or compostable nature. As a result, the demand for primary resources is expected to decline. The packaging sector is one of the key sectors in which the European Commission proposes the implementation of circular principles and the promotion of bioplastics (European Commission, 2018; European Commission, 2020). It is a sector that generates a large demand for plastics, so it has great potential for the development of biodegradable and compostable packaging, including disposable packaging (which most often pollutes beaches) (European Commission, 2020). Compostable packaging responds to modern trends such as take-away, eco-products, a healthy lifestyle and climate protection.

Currently, the level of use of bio-packaging in the EU economy is low (European Commission, 2018). The EC emphasizes that the development and increase in the share of innovative plastics in the market, including in the packaging sector, requires the development of a common legal framework, proper labelling of packaging, and a system for their collection and processing. (European Commission, 2018). The development of compostable packaging is currently facing the following barriers, packaging properties, economic barriers, legal barriers, infrastructure barriers, social barriers and barriers to corporate environmental responsibility. The key is their gradual reduction with the parallel involvement of stakeholders in the supply chain of compostable food packaging. The gradual elimination of barriers will increase the

use of compostable packaging, bringing economic, environmental and social benefits. The main purpose of the article is identification of the main barriers determining the low level of compostable food packaging in the circular economy in the country. The following research questions support the achievement of the main goal:

1. What characterizes and how are compostable packaging currently used on the food market?
2. How does compostable packaging implement the principles of circular economy?
3. What barriers limit the use of composting packaging in the food sector?

The considerations and research presented in the article should be seen as a voice in the ongoing discussion.

2. Theoretical Review

2.1 Compostable Packaging

In the scientific technical literature, the concept of composting is considered in many ways. A wide range of studies on physical, chemical and biological aspects should be pointed out here. In the field of social sciences, in relation to management and economics, however, the concepts related to compostable packaging belong to a definite minority. The Google Scholar database, as the most common, indicates about 13,000 results over the last 10 years. At the same time, the most publications concern the scope of agriculture, such as the shelf life of products in compostable packaging (Owoyemi *et al.*, 2021) or issues related to the biological characteristics of the raw material (microbiological activity) (Zhang *et al.*, 2017) and the technological possibilities of its use (Barletta and Gisario, 2021).

However, from the point of view of consideration in the article, the main emphasis is placed not only on the attempt to determine the types of compostable packaging, but also on the issue of management and economics of the market. Especially that there are already few studies in the above scope and in relation to the circular economy, e.g. in the field of production and consumption of compostable packaging in the context of circular economy (Casarejos *et al.*, 2018).

However, by narrowing the literature review to the social sciences, the following scientific bases were selected, Emerald, EBSCO and Web of Science. The Emerald database returned only 88 results, with most of them again being technical studies. The EBSCO database returned more than 380 results, but after narrowing the search to scientific publications only, there are only 85 views and again most of them concern the technical aspects of the raw material and packaging. In the case of the Web of Science database, there are 26 results – the least, also mostly in the field of technical sciences.

Nevertheless, it is possible to determine how compostable packaging is defined. The simplest definition is a reference to the raw material from which they are made. Compostable packaging must be made of biodegradable polymers from natural resources and must undergo a composting process. Composting is a biological process that takes place in an aerobic environment, allowing the production of compounds that do not harm the environment and are absorbed through this environment (when the product is humus or compost) (Diaz *et al.*, 2002).

Compostable packaging is easy and has a short processing cycle, and the processing products feed bio-waste, which, when converted into compost, can also support e.g. inorganic fertilizers.

The type of compostable packaging depends on the raw material. It is most often lactic acid (PLA), TPS (thermoplastic starch) and PCL (polycaprolactone) in the form of wrapping film, plastic bags, disposable dishes (cups, plates) and disposable packaging (water bottles) (Czarnecka-Komorowska and Wiszumirska, 2020). It should also be pointed out that compostable packaging constituting waste is one of the elements of extensive research on the impact of this waste on the environment (Kościelna, 2017), and even contributes to the so-called packaging policy in the world (Pawlak, 2020).

The challenge in shaping packaging policy is to draw attention to the compostable packaging market as an alternative to traditional packaging. In addition, an important aspect of the circular economy, discussed below, is the closure and stability of the circulation in the supply chain of compostable packaging. Compostable packaging can be treated as a resource for flow stability in the supply chain when the number of external factors is characterized by high variability (Marzantowicz, 2018).

2.2 Compostable Packaging in Relation to CE Principles

Compostable packaging is produced using renewable natural raw materials, so it can be considered that it belongs to the group of ecological and sustainable products. They are characterized by specific technical characteristics, the possibility of use and development. As indicated, the economy of the EU and the Member States is moving more and more towards circularity. The development of the market of compostable packaging for food should therefore clearly fit into the implementation of CE principles. So the question is, how do compostable packaging implement the principles of circular economy? The answer requires an approximation of what is meant by the concept of circular economy and what principles accompany it. The concept and principles have been well recognized in the literature (Reike *et al.*, 2018).

The Ellen MacArthur Foundation emphasizes that the goals of the Circular Economy are to design waste so that it can be reused, to keep products and materials in the economy for as long as possible, and to regenerate natural systems by

returning nutrients to the environment (Ellen MacArthur Foundation, 2017). Circularity deviates from the linear approach in the economy based on the "take-make-dispose" model (Ellen MacArthur Foundation, 2013). Waste in circular terms is a valuable raw material. Murray and others propose a definition, "The Circular Economy is an economic model where in planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being" (Murray *et al*., 2017).

The definition combines economic, environmental and social aspects, which confirms the importance of CE in achieving the global Sustainable Development Goals. CE is based on principles that are presented in various summaries. The basic division in force in the EU waste hierarchy indicated in the EU Directive of 2008 (European Parliament, 2008, article 4), takes into account the principles of 3R, i.e., Reduce, Reuse and Recycle. Achieving maximum effects requires taking into account in the economy a detailed palette of circular principles, which is formed by a set of 10R (Principle) (Vermeulen *et al*., 2018). The analysis of the links between the 10R principles and biopackaging indicated that this type of packaging is part of the implementation of the principles R0, R1, R7, R8. Table 10 attempts to justify the development of the circular economy through the development of compostable food packaging.

Table 1. *Compostable food packaging and its reference to CE principles*

No	Principle	Implementation of CE principles *versus* compostable food packaging
1	R0, Refuse	• The production of compostable packaging does not require the use of materials hazardous to the natural environment, human life and health. • Production processes can be based on the reduction of waste generation, including those that are difficult to manage. • The consumer may resign from buying food in plastic packaging by choosing in compostable packaging.
2	R1, Reduce	• The production of compostable packaging is based on the use of renewable natural resources such as sugarcane, thus reducing the demand for non-renewable resources. • The development of innovations and technologies in the production of compostable packaging is an opportunity to reduce the amount of renewable and non-renewable raw materials used (e.g. electricity) per unit of production. • Packaging production can be carried out using renewable energy sources.
3	R2, Reuse	Compostable food packaging due to its limited properties and purpose: • They may not be reused by another consumer for the same or a different purpose, or the same consumer may use or give new ones in the short term,
4	R3, Repair	Compostable food packaging due to its limited properties and purpose: • have no way to repair *or* refurbish *or* remanufacture; • at the moment, it is not possible to use compost to re-produce compostable packaging
5	R4, Refurbish	
6	R5, Remanufacture	
7	R6, Re-purpose	

8	R7, Recycle materials	• Compostable packaging is organically recycled • The resulting compost, depending on the degree of pollution, can be used in gardening or agriculture. As a result, valuable nutrients are returned to the natural environment.
9	R8, Recover energy	• In addition to compost, the effect of circular management of bio-waste is biogas. Biogas can be used for the production of heat and electricity.
10	R9, Re-mine	• The limited properties and purpose of compostable food packaging make it impossible to extract them from landfills.

Source: *Own elaboration based on: Vermeulen et al., 2018, pp. 2-5; Reike et al., 2018; European Investment Bank, 2020, p. 15.*

To sum up, the development of compostable packaging for living is consistent with the principles of CE and makes it possible to achieve the sustainable development goals. The increase in the use of biopackaging in the economy gives an opportunity to reduce the negative consequences caused by plastic packaging. The challenge is the gradual introduction of biopackaging into food while optimally designing the effective management of bio-waste, which accounts for the greater part of municipal waste.

3. Research Methodology

The study relied on the Individual In-depth Interview (IDI) method. Several dozen participants were studied. In-depth individual interview represents a method of qualitative research. In this type of research, the emphasis is on the fact that – thanks to the use of special research techniques – we get to know more thoroughly and understand the issue under consideration, as well as the correlations between its individual elements. Quantitative measurement is not applicable.

Qualitative research highlights the role of applying a technique that will allow to achieve unique knowledge from participants. Thanks to this assumption, it is possible to analyze the phenomenon considered in the study, and at the same time the participants of the study are not limited in their answers. The answers obtained from the participants can be reduced to individual, more universal sets only after they have been articulated by the participants in the study. It should be noted that in quantitative studies it is the opposite, conclusions are articulated on the basis of strictly aggregated variants of responses. Thus, in a qualitative study, it becomes possible to collect diversified views and diverse perspectives on the analyzed topic. These opinions are only then collected into more general collections, in order to give greater precision as well as transparency to the results obtained.

An individual in-depth interview is conducted with one person. The data of interest to the researcher is obtained in the course of an individual, honest and direct conversation with the participant. This study is an in-depth interview, thanks to which the researcher asks the most relevant questions in relation to the information he wants to receive. The IDI method ensures freedom of expression. In this way, it

verifies the attitudes, feelings or motives of the participants. It requires more time for the researcher to devote more time than a survey study, but it determines the achievement of in-depth answers. It is possible to conduct more such interviews, which will make the results even more attractive.Due to the fact that the test was performed using the qualitative method, the research sample was selected in a deliberate way. Thus, it was not necessary, as in the quantitative method, to determine the closer socio-demographic cross-section of the studied population or the level of confidence, and the size of the research sample was not so important for the correctness of the results.

It was completely irrelevant to take into account the statistical error, because in qualitative studies in which the research sample was selected intentionally, it is not subject to measurement. The selection of the research sample, carried out intentionally, allowed to determine the questions shaping the interview scenario. The preparation of the interview scenario made it possible to undertake it with the participation of the participants. The researchers conducted in-depth interviews by meeting directly with the participants, and thus established direct interpersonal relationships with them. The collection of data allowed the synthesis of responses. The study was conducted in two stages. The first involved conceptual work, in which the research problem was clarified and the purpose of the research was determined. In the second stage, the assumptions were implemented and the IDI study was carried out, then the results related to the barriers to the development of the compostable packaging market in the food sector were selected (Brzeziński *et al.*, 2021).

4. Results

As a result of the study, barriers to the development of the compostable packaging market in the food sector were determined. A breakdown of barriers is presented in Table 2.

Table 2. *Summary of identified barriers to the development of the compostable packaging market.*

Economic barriers	Packaging features	Social barriers
Legal barriers	Infrastructure barriers	Environmental corporate responsibility

Source: *Own elaboration based on the results of the IDI study*.

Economic barriers were most often identified. There are two basic problems to be distinguished here. The surveyed companies consider the economic efficiency of the production of compostable packaging to be the first of the problems. This is due to the difficulty in obtaining raw material in close proximity to the place of production, but also the high costs of importing raw material. Additional problems are generated by the fact that there are a very small number of potential producers of raw material, hence the limitations in terms of the possibility of diversifying supplies, but also

their volume. It should therefore be considered that the presented problems concern the costs of the supply chain concerning, in particular, expenditures on R&D, and difficulties in logistics, as well as the costs associated with obtaining certificates and integration of certification for all participants in the supply chains of the compostable packaging itself as well as food in these packages. The second aspect is the problems related to the price. And here it is necessary to point out the relatively high price of production and sale of such packaging. Packaging is more expensive, which is why it also affects the price of food in compostable packaging. Often it is a barrier to the choice of conventional packaging.

The properties of compostable packaging constitute a physical barrier. Here it is necessary to pay attention to the durability of such packaging. Conventional plastic packaging is not only cheaper, but also has an advantage in ensuring the quality and safety of packaged products. In addition, plastic packaging can be recycled by introducing reusable packaging. The life cycle of composted packaging is shorter. An additional problem is the way in which compostable packaging is labelled and identified, especially from the consumer level. By contrast, insufficient consumer awareness of the identification of compostable packaging is an additional factor limiting the marketing and sale of compostable packaging for food.

One of the main barriers to the development of compostable packaging is *the poorly developed infrastructure for organic recycling.* There is a lack of adequate number and spatial availability of waste management installations. The main reasons for this situation include limited public funding. The construction or expansion of the appropriate technical infrastructure requires considerable financial resources and sufficiently large areas. Investments are time-consuming and their process is prolonged by lengthy procedures and building permits. Financial resources in the public sector are often limited and public-private investment is still difficult to implement. There is also a shortage of private investors on the market who would be willing to invest in the development of infrastructure for organic recycling. Private capital does not see the potential profits from this type of investment, as well as the dynamically changing provisions of waste management law.

Another reason is the relatively "fresh" emergence of the need for the development of *bio-waste management infrastructure.* The obligation to segregate waste introduced in 2019 has resulted in a growing demand for composting plants and energy recovery installations from biodegradable waste. Currently, the investment gap is a perceived need in the public sector and is becoming a topic of discussion and investment plans. However, investments in infrastructure may be limited due to protests from the local community, which does not agree to the location of the composting plant in the municipality (unpleasant odors, increased traffic, road and technical noise).

An important barrier to the development of the compostable packaging market is the shortage of *legal provisions* both at the European Union and national level regarding

the organization of compostable packaging management in accordance with CE principles. There is a lack of a systemic approach in the creation of legal regulations for the needs of CE. The rules are often inconsistent and difficult to interpret for businesses and public entities. It should be noted that the implementation of new waste management regulations at the state level, which will apply to all municipalities, may be difficult to implement, especially by economically weaker municipalities. It may be necessary to provide financial support to municipalities for the implementation of regulations and for the transition to a circular economy.

So far, there are no clear regulations dedicated to the design and use of biopackaging. There is a lack of regulations governing the labelling of biopackaging. At present, there are also no financial incentives (e.g., financial incentives) for companies producing compostable packaging or switching partly or in full to the production or use of biopackaging for food. Current laws are not effective in *eliminating greenwashing*, which is an unhealthy competition for compostable packaging.

The current legal provisions give municipalities the opportunity to choose between total or separate waste segregation into kitchen waste and green waste. The lack of a uniform and clear regulation results in uneven waste streams redirected to waste management plants. At this point, it should be emphasized that the current demand for compost produced in plants is diverse. Most often, there are no regular recipients, which affects the need for its storage and additional costs.

An important barrier to the development of the food packaging market is *insufficient communication between the public and private sectors.* Proper design of legal regulations and waste management policy requires a diagnosis of the needs of stakeholders in the circular supply chain of biopackaging and public resources that can be used for the development of the biopackaging market. There is a deficit in the exchange of information and communication in the design of waste management law and CE, between law-making bodies, experts in the field of biopackaging, local waste management entities.

The social barrier is non-compliance with the principles of waste management and low knowledge about compost packaging of the society. The reason for the situation is the deficit of public, private and social information and educational campaigns, competitions addressed to residents and compulsory education in schools on circular economy, distinguishing between types of food packaging as well as other environmental problems of the modern world (e.g., water deficits). There is also a lack of intergenerational communication that could enable the diffusion of knowledge in society. A shortage of mobile applications, digital educational games and a low level of use of social media in the dissemination of knowledge are also identified. There is a lack of educational paths and information in the space of cities. A big difficulty is the lack of proper labelling of composted packaging and information on the packaging, what to do when food is not consumed.

Residents are often reluctant to segregate waste due to previous habits, lack of space for storing waste in homes and lack of individual responsibility for waste segregation. Bio-waste is often contaminated (plastic bags, glass). In multi-family buildings, the quality and quantity of waste is collectively responsible (lack of *a door-to-door* system), which means that households often do not identify with the obligation of proper segregation. In addition, the process of waste segregation and storage for households is unattractive due to damaged waste collection points (pergolas), lack of implemented innovative solutions and technologies, or low frequency of bio-waste collection.

The last of the key barriers stems from restrictions *on environmental corporate responsibility.* These restrictions are related to the priority of economic goals in economic activity, but also to the initial stage of greening enterprises in the country. Businesses will not only have to face EU guidelines on extended producer responsibility, including participation in the costs of greening and economic activity. The problem in this situation is the discrepancies in the formal and legal conditions at different levels of law organization in the European Union and the country. Nevertheless, the biggest challenge is the costs of extended producer responsibility, which will naturally be passed on to consumer and business customers. It is worth mentioning here that compostable packaging is not only an element of greening the activities of free market enterprises, but also institutions in the organizational structure of the country at the local, provincial and national level – e.g., in the field of problems related to waste management.

5. Discussion

The results of the study establishing a catalogue of barriers are crucial for recognizing the determinants of compostable packaging supply chains in a circular economy. Especially in the context of the short life cycle of compostable packaging, these barriers can in principle prevent the optimal functioning of supply chains. In this context, it is difficult to give weight to the importance of these barriers. They affect both the business and consumer space as well as the business environment and related formal and legal conditions.

Nevertheless, when trying to give weight, the first thing to do is to pay attention to economic barriers. These barriers are often a decisive factor in launching a supply chain. Then, formal and legal barriers will be important, because they normalize economic activity in general and thus condition the functioning of compostable packaging supply chains.

Finally, all social, infrastructural and environmental barriers are the limiter of the circular economy. There are problems with waste management, and therefore it is difficult and sometimes impossible to fulfill all the postulates of a circular economy. It should be pointed out here that the life cycle of compostable packaging is specific.

The raw material obtained from the environment returns to the environment but in a different form, which, however, still implements the aforementioned circularity.

In fact, the catalogue of barriers is wide. Hence, one should expect an equally wide catalogue of solutions to these problems. At the same time, it is important that these solutions are prepared and carried out systemically. A compromise between the regulator, the companies involved in the supply chain and the customers – users of compostable packaging – need to be reached. In a diversified system of needs, it is important to ultimately lead to:

- competitiveness of compostable packaging on the food packaging market,
- unification of formal and legal requirements,
- development of infrastructure for packaging processing,
- support for business activity in the field of its greening,
- broad activities raising awareness of the demand and supply side.

Closing the economic cycle in terms of the flow of composite packaging requires a holistic approach to solutions to the problems presented. The postulates of the circular economy, despite the indicated barriers, can be effectively implemented because compostable packaging is characterized by:

- environmentally safe extraction of raw material,
- confirmed potential to increase the share of compostable packaging in the food cycle,
- short life cycle,
- clean return to the environment by rapid decomposition – the possibility of using biogas obtained by composting,
- implementation of environmental postulates of sustainable development,
- constitute an innovation and are therefore a factor influencing the competitiveness of enterprises on the food market.

6. Conclusions

The compostable packaging market is rather at a growth stage. The early period of development of this market does not yet allow for a full assessment of its potential. Nevertheless, it should be pointed out that the supply chains of compostable packaging and the supply chains of food in compostable packaging are already in place successfully. European and local sources do not provide specific data on the production of compostable packaging. The reference of compostable packaging only to waste is, however, scarce, so it should be assumed that the research platform for the use of compostable packaging in the circular economy is still open.

The aim of the article was to present the barriers to the development of the compostable packaging market and taking into account the considerations carried

out, as well as the results of the study carried out, it should be considered that the goal has been achieved. On this basis, the following conclusions of a general nature should also be indicated:

- from the formal and legal point of view, the implementation of the postulates of circular economy in the field of the compostable packaging market is rather difficult and requires consistent regulatory solutions at the European and national level,
- the industrial infrastructure is insufficient to successfully and on a large scale compost waste from the packaging of compostable,
- however, the changing infrastructure has the potential to support the development of the market for compostable packaging for food,
- social barriers relate mainly to the awareness of consumer protection and social pressure exerted on manufacturers of conventional packaging,
- food and compostable packaging supply chains implement environmental and social demands of sustainable development, including the circular economy,
- the price of production and sale of compostable packaging, which is a barrier, depends on legal conditions, but also on the expansion and diversification of raw material resources and its suppliers.

In view of the general conclusions thus drawn, it should be assumed that the market potential is high. This again opens up the area for further research, in particular in the following areas:

- reconfiguration of supply chains (including companies that are links in the supply chain) of compostable packaging,
- optimization of food supply chains in the system of environmental requirements of sustainable development with the use of innovations such as compostable packaging,
- the impact of eco-innovations, including compostable packaging, on customer and consumer behaviour,
- economics of enterprises in the area of greening of activities,
- external and internal conditions of the market of compostable packaging for food,
- stimulant and destimulants for the development of the compostable packaging and waste market,
- re-delimitation of the circular economy based on short life cycles of compostable packaging,
- the potential of uniform formal and legal regulations at European and national level, with particular emphasis on the impact of gaps in these regulations on the greening of enterprises and supply chains,

- the inclusion in the market value of compostable packaging also of intangible assets in terms of the positive effects of composting processes on the environment and society.

Of course, the catalogue of further directions of research is not closed. This is due to the fact that compostable packaging was early recognized as an eco-innovation and so-called good waste. However, it should be assumed that the research space is still open, but the full recognition of the new market of compostable packaging as a key element in the implementation of the postulates of the circular economy is a rather distant future.

References:

Barletta, M., Gisario, A. 2021. Laser sealing of compostable packaging solutions: Experimental approach and adhesion mechanisms. Optics and Lasers in Engineering, 137, 106369.

Brzeziński J., Wieteska G., Marzantowicz Ł., Ocicka B., Tyczyna E., Wieteska-Rosiak B. 2021. Łańcuchy dostaw bioopakowań w gospodarce o obiegu zamkniętym - koncepcja badań. Miesięcznik Marketing i Ryne," (1231-7853), 28(3), 3-13.

Czarnecka-Komorowska, D., Wiszumirska, K. 2020. Zrównoważone projektowanie opakowań z tworzyw sztucznych w gospodarce cyrkularnej. Polimery, 65.

Czop, M., Kościelna, A. 2017. Badanie właściwości wybranych odpadów opakowaniowych pod kątem ich ponownego wykorzystania. Archiwum Gospodarki Odpadami i Ochrony Środowiska, 19(1).

Diaz, L.F., Savage, G.M., Golueke, C.G. 2002. Composting of Municipal Solid Wastes. In: Tchobanoglous, G., Keith, F. (eds). Handbook of Solid Waste Management (Second Edition). USA: McGrawHill Companies, Inc.

European Commission. 2018. COM(2018) 28 final. A European Strategy for Plastics in a Circular.

European Commission. 2020. COM(2020) 98 final. A new Circular Economy Action Plan For a cleaner and more competitive Europe.

European Investment Bank. 2020. The EIB Circular Economy Guide Supporting the circular transition. EIB, 15.

European Parliament. 2018. Plastic in the ocean: the facts, effects and new EU rules, https://www.europarl.europa.eu/news/en/headlines/society/20181005STO15110/plastic-in-the-ocean-the-facts-effects-and-new-eu-rules.

European Parliament. 2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives. Official Journal of the European Union L, 312(3).

Ellen MacArthur Foundation. 2013. Towards the circular economy. Journal of Industrial Ecology, 2, 23-44.

Ellen MacArthur Foundation. 2017. What is The circular economy? https://www.ellenmacarthurfoundation.org/circular-economy/what-is-the-circular-economy.

Marzantowicz, Ł. 2018. Stabilność łańcucha dostaw–stan, poziomy i zasobowe uwarunkowania. Gospodarka Materiałowa i Logistyka.

Murray, A., Skene, K., Haynes, K. 2017. The circular economy: an interdisciplinary exploration of the concept and application in a global context. Journal of business ethics, 140(3), 369-380.

Owoyemi, A., Porat, R., Rodov, V. 2021. Effects of compostable packaging and perforation rates on cucumber quality during extended shelf life and simulated farm-to-fork supply-chain conditions. Foods, 10(2), 471.

Pawlak, K. 2020. Determinanty kształtowania polityki opakowań w Polsce i na świecie. Ekonomia, 26(1), 55-70.

Reike, D., Vermeulen, W.J., Witjes, S. 2018. The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resources, Conservation and Recycling, 135, 246-264.

United Nations. 2021. 17 Goals to Transform our World. https://www.un.org/en/exhibits/page/sdgs-17-goals-transform-world.

Vermeulen, W.J.V., Reike, D., Witjes, S. 2018. Circular Economy 3.0: getting beyond the messy conceptualization of circularity and the 3R's, 4R's and more…. https://www.cec4europe.eu/wp-content/uploads/2018/09/Chapter-1.4._W.J.V.-Vermeulen-et-al._Circular-Economy-3.0-getting-beyond-the-messy-conceptualization-of-circularity-and-the-3Rs-4-Rs-and-more.pdf.

Zhang, H., McGill, E., Gomez, C.O., Carson, S., Neufeld, K., Hawthorne, I., Smukler, S.M. 2017. Disintegration of compostable foodware and packaging and its effect on microbial activity and community composition in municipal composting. International Biodeterioration & Biodegradation, 125, 157-165.