Biodegradable and Compostable Products – Essential Components for the Development of a Sustainable Bioeconomy

Gabriela-Iuliana Paraschiv (Ganea)
The Bucharest University of Economic Studies, Romania
gabriela.iuliana.ganea@gmail.com
Elena Condrea
"Ovidius" University of Constanta, Romania
elenacondrea2003@yahoo.com
Valentina Olteanu
Procter & Gamble, Romania
valentinaolteanu7@gmail.com

Abstract

In this paper we aim to highlight the importance of developing the industry of biodegradable and compostable products - an essential component of a sustainable bioeconomy, in terms of reducing the impact of economic activities on the environment, as well as ensuring quality of life. Romania, a country member of the European Union, has adopted all European regulations in the field, whilst supporting the development of regulations, policies, strategies, support and financing designed to help investors in the market.

In the first part of the paper, we will make a brief presentation of the current situation of the plastics industry and then present the main aspects of biodegradable and compostable products, for the theoretical understanding of the problems to be analyzed, as well as showcasing a clarification of the basic concepts and the links between them. In the last part, we will highlight the importance and benefits of the development of the market for biodegradable and compostable products (especially packaging), in the context of a sustainable bioeconomy, a renewable segment of the circular economy.

Key words: biodegradable, compostable, sustainable bioeconomy, circular economy
J.E.L. classification: L65, M11, O13, Q01, Q16

1. Introduction

We live in a world where resources are limited. Global challenges, such as climate change and the degradation of land and ecosystems, together with a growing population, force all the world's economies to seek new ways of production and consumption that respect the ecological limits of our planet. At the same time, the need to ensure sustainability is a strong incentive to modernize our industries and strengthen the position of European Union countries in a highly competitive global economy, thus ensuring the prosperity of its citizens. To address these challenges, we need to improve and innovate how we produce and consume food, products and materials in healthy ecosystems through a sustainable bioeconomy. It can turn scrap and biological waste into goods of value.

2. Theoretical background

2.1 Plastic, indispensable in the modern economy but with negative consequences on the environment and human health

The word "plastic" in Latin - "plasticus", itself derived from the Greek "plasticos" which means "in relation to modeling". The basic feature of this material, "plasticity" - can be given by modeling, the desired shape, combined with a low price, has determined that this material to become indispensable in our modern economy. Moreover, it combines other valuable qualities, both physical such as: hardness, low density, breaking strength, heat resistance, as well as chemical: it rejects the achievement of a connection with water (hydrophobia) and biological inertia. Consequently, it follows that the notion of "plastic" has nothing to do with the raw material from which it is made (organic or inorganic, petroleum, etc.) or its biodegradation / composting capacity.

Plastics are used in many areas of the economy, such as the packaging industry, the transportation industry, construction health, the electronics industry. Plastics production is expected to double in the next twenty years and almost four times by 2050.

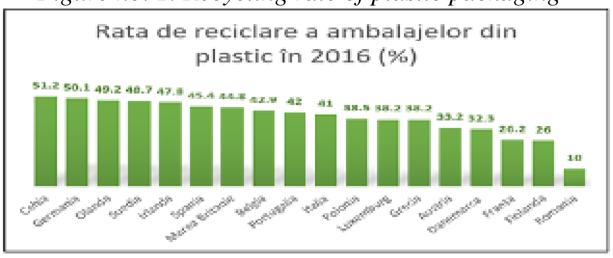
From a financial point of view, the plastics industry has a contribution of 27.50 billion euros to public finances in European countries and provides more than 1.5 million jobs in Europe. (Gontard, 2018).

The plastic packaging production sector is based on a linear value chain, which consists of extracting, producing, consuming and disposing, which has significant economic and environmental disadvantages.The circular economy is an alternative to the so-called "linear" economy, which is currently dominant - less than 10% of material flows are currently closed (Hoogzaad et al., 2018).

Plastic generates significant negative externalities in the field of degradation of natural systems due to leaks, especially in the ocean; greenhouse gas emissions from the production and subsequent incineration of plastic; and the impact on health and the environment due to the components, which are of great concern.

Currently, over 40% of annual plastic consumption is represented by disposable packaging. Regarding the recycling of these products, the situation in our country is worrying - we recycle less than 10% of the plastic we use (Biodeck, 2018), which puts us at the tail end of Europe, as shown in the image below.

Figure no. 1. Recycling rate of plastic packaging



*Source:*Plastic Europe

2.2 The transition from plastic products to biodegradable and compostable products, an alternative in the context of developing a sustainable bioeconomy

Despite all the measures imposed to improve the collection and processing of infrastructure, the leakage of plastic packaging into the environment can not be completely eradicated. In order to significantly reduce the negative impact on the environment of plastic packaging, it is necessary to produce biodegradable packaging in nature, both in soils and in water.

In this context, plastics must be replaced with a resource other than petroleum products such as plants, which are biodegradable, ie are able to decompose naturally, without persisting for years and decades in the environment (Bruzaud, 2018) .

3. Research methodology

The research methodology used is that of scientific documentation by studying the specialized bibliography, publications and scientific articles published in the international research flow, a method that allowed us to highlight the importance of moving to a sustainable bioeconomy, in the biodegradable and compostable products sector. uses renewable raw materials, a solution to reduce the use of fossil raw materials and the negative impact on the environment by simplifying the recycling chain of bio-waste.

The main topic of research is biodegradable and compostable products - especially packaging and disposable products, in the context of a sustainable European bioeconomy, which supports the modernization and consolidation of the EU's industrial base by creating new value chains and greener industrial processes more cost-effective.

4. Rezults

4.1 Bioplastic - from the beginning to the end of life

The term "bioplastic" has many meanings, representing products of different materials and properties. The prefix "bio" = life, can refer to the origin of plastic or the fact that at the end of the life cycle it is biodegradable.

Bioplastics can be classified into three broad categories:

1. Biological origins - generally from plants but end of life non-biodegradable
2. Origins from fossil fuels and biodegradable end of life
3. Biological origins and biodegradable end of life

In a circular, sustainable economy, the third category is the ideal one.

Table no. 1. Classification of plastics

Origin / The end of life	Organic base	Petrochemical (No bio resources)
Biodegradable (at minimum requirements industrial compost)	starch polymers of potatoes, starch, or cellulose - PHA (polyhydroxy alkanoates) - PLA (polylactic acid) - bio-PBS (poly (butylene succinate)	- PCL (polycaprolactone) - PBAT (polybutylene adipate-co-terephthalate) - PBS (polybutylene succinate) - copolyester
biodegradable	- bio-PE (bio-polyethylene) - Bio-PET (bio-terephthalate ethylene) - bio-PTT (bio-terephthalatetrimethylene) - polyamides (PA) and biosourced polyurethane (PUR)	- PE (polyethylene) - PET (ethylene terephthalate) - PS (polystyrene) - PP (polypropylene) - PVC (polyvinyl chloride) - PA (polyamide) and PUR (Polyurethanes)

Source: Information report - Biodegradable and compostable bioplastic

Bioplastics are plastics produced from renewable biomass sources, such as:
-vegetable oils extracted from flax seeds, sunflower, soybeans, olives, palm, etc .;
- starch and sugars obtained from corn, potatoes, beets, sugar cane, rice, etc.
- natural fibers such as straw, wood, sawdust, hemp, cotton, etc .;
- animal proteins and lipids, such as whey, casein, fat or gelatin;
- recycled food waste, etc.

The processes used to obtain biodegradable products are biotechnological, such as extraction or fermentation or chemical processes such as dehydration, hydrolysis, etc.

Organic polymers can have a structure of 2 types: a. one identical to that of fossil polymers or b. a completely different from the already known petrochemical polymers derived from starch. (ADEME, 2013).

Currently, it is known that "plastics" can be made from plant resources. Today, whatever plastic product we can think of can be replicated using only materials derived from plants, if only into the stage of R&D (Bruzaud, 2018).

As we saw in the first part, even if the plastic used to obtain an increase in efficiency in the use of resources during their period of use, the carbon footprint is not one than one can easily ignore.

When we talk about putting to use raw materials that have a renewable power instead of petrochemicals in the packaging industry reduces greenhouse gas emissions at all stages of the lifecycle - production, processing and post-consumption.

4.2 How to define biodegradability?

„A material is considered "biodegradable" if the decomposition under the action of microorganisms results in water, carbon dioxide and / or methane and by-products (biomass, residues) that are not toxic to the environment" (ADEME, 2005).

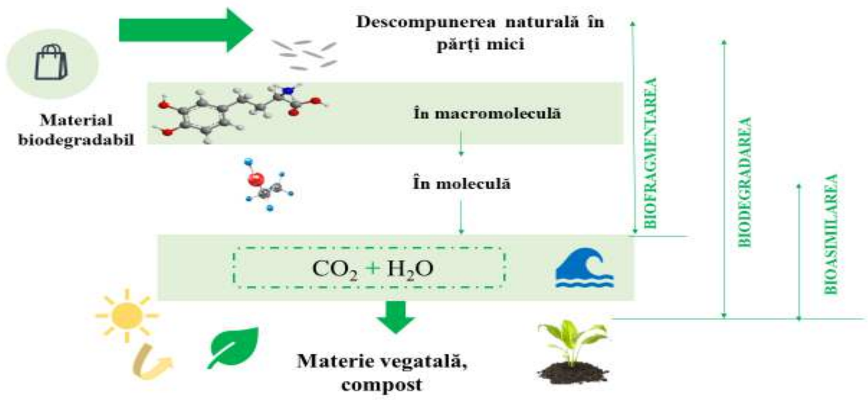
The definition presened above is the one which is used commnly in at least five standards (such as ISO and CEN) on biodegradation requirements.

Biodegradation is determined by a number of factors that can be classified under more than one category, but the most encountered categories are linked with the nature and there we can talk about the physico-chemical elements (temperature, humidity, pH) or microbological (here it can be more fluctuating taking into account both the nature or the amount of the micro-organism).

Along the biodegradation process, physical processes take place, by breaking the material into smaller particles, followed by a series of chemical processes and finally, when the dimensions of the chains are very small, which means their molecular weight is very low and simultaneously the degree of oxidation becomes high, is the moment when biological degradation caused by microorganisms takes place (Ghiglione, 2018).

There is the process called „composting" and it's representing the transformation of aerobic nature. More specifically, this process can take place in 2 ways depending on the existence or absence of oxygen. When oxygen is present the reaction is exotermic and in the case of no oxigen there is also biogas obtained throguh the anaerobic reaction. The resulting products are compost, which is a fertilizer containing humic compounds and carbon dioxide.

Figure no. 2. The process of aerobic biodegradation (with oxygen) - in a temperate, humid environment, with the presence of microorganisms



Source: ADEME, 2015

As can be seen from the very suggestive scheme, above, in addition to compost, there is a mixture of water and carbon dioxide, a mixture also used in the process of photosynthesis. We can speak here of a closed life cycle. Compost can be used in agriculture, instead of chemical fertilizers or in works to improve and fertilize the soil.

Composting is easy to implement and allows local management without waste transport - Proximity compost. In fact the solution is not only easy to implement, it's also cheap given that there is no material being moved anywhere complex and it's also efficient (ADEME, 2015).

Even here, there are more than one manners of composting, one is a lower-scale one (home composting) and the other one where one can benefit of the scale is the indutrial composting and they have commonalities (such as the decomposition is carbon dioxide, water, compost and the final result – the compost can easily be used as fertilizer), yet this is the simple part. In temrs of differences, of course when composting at home there are more variables such as the environment (which can be controlled industrially), the temperetatur as well as the moisture level – this is all stable in the industrial part as a result of the scale to which things can be done and the existing of more technological resouces –this also has an impact on the biodegradation range which in home-composting varies whilst in the industrial one is quite well-defined.

We notice that in industrial composting plants, the environment, humidity and temperature are controlled, which reduces the composting period. Because the fermentation process is an exothermic process, the temperature naturally rises to 50 ° - 60 ° C.

In view of the above, it is safe to say with no argument that any plastic that has a biodegradable nature should not be sent landfills or incinerated at the end of its life-cycle as their specificity is biodegradability. Actually, biodegradability could be advantageously used in compost or biogas.

At European level, the standard governing composting requirements for packaging is EN 13432. Packaging that can be recovered by biodegradation and composting must meet four requirements, set by the standard, in order to be accepted for industrial composting:

- **Composition**: material must have a maximum level of volatile solids, fluorine and heavy metals;
- **disintegration**: the original material must disintegrate under composting conditions;
- **biodegradation**: at least 90% of the reference substance must degrade in less than 6 months; The quality of the final compost and the ecotoxicity must not be influenced by the packaging added to the compost and must not be dangerous for the environment.

One of the requirements of the standard is to perform eco-toxicological tests on the final compost. The result must indicate a success rate of at least 90% of that of the control compost.

With regard to home composting, the same requirements as those of standard EN 13432 are used as regards the composition of the raw material, the quality of the final compound and the ecotoxicity, but the biodegradability thresholds differ (over 90% in less than 12 months) disintegration, because the composting periods are longer and are mainly due to the lower biodegradation temperature (approx. 25 ° C).

The identification of compostable packaging is made on the basis of labels certified on international quality standards.The certification body provides assurance of compliance with the standard, on a permanent basis, through continuous surveillance or recertification audits.

There two types of „OK compost" labels that certify each one something different: the first one is of industrial nature and certifies fact that the products meet the respective EN 13432 standard – attesting to their biodegradable nature under industrial conditions whilst the 2nd one, of home nature, confirm that the product is considered biodegradable and safe to compost in home-conditions.

Figure no. 3.examples of packaging compostability certification logos

Source: Biodegradable & Compostable Eco Pack

The factors that influence the biodegradation rate are:

- physico-chemical: temperature, humidity, pH that we have already presented;
- microbiological: quantity and quality of microorganisms in the degradation environment;
- the molecular structure and properties of the polymers of which the material is composed. As such, where there is a low molecular weight polymer and a high degree of oxidation the biodegradation is taken care of by microbial enzymes.
- hydrophilic or hydrophobic character of the material;
- crystallinity;
- manufacturing process of the material (extrusion, injection, thermoforming, etc.)
- material formation conditions (temperature, pressure, use of plasticizers or additives).

Depending on the type of manufacturing process and the formation conditions, materials with very different characteristics will result, both in terms of their crystallinity, their composition or their behavior towards water, inducing different biodegradation methods (ADEME, 2005).

4.3. Categories of biodegradable plastics

Starch-based plastics

Biodegradable starch-based plastics are the most widely used, representing about 50% of the bioplastics market.

Cellulose-based plastics

Cellulose fibers are less hydrophilic than starch so, when added to it, they improve the water resistance and mechanical properties of the final product.

Protein-based plastics

Biodegradable products can be obtained from proteins from different sources: gluten and wheat casein as well as soy protein. Soy protein has been used in plastic production for over a hundred years.

Bacterial natural polymers

Polymers such as PHA are produced by microorganisms by fermentation, to be more specific these polymers are synthesized by plants or microorganisms and in turn they have a biodegradable nature in normal conditions (Gontard, 2019).

Synthetic polymers Base-bio

Synthetic polymers are made by polycondensation. The best known is PLA (polylactic acid), resulting from the polymerization of lactic acid molecules. PLA, which is a synthetic material, is biodegradable in compost under industrial conditions.

Polymers derived from petrochemicals

They are materials obtained from biodegradable synthetic polymers, especially aliphatic polymers, such as PCL (polycaprolactone) and PBS (polybutylene succinate),

4.4 Areas of use of biodegradable and compostable products

Biodegradable and compostable products are mainly used in the manufacture of disposable items. Special plastic packaging and bags are among the first products made of biodegradable bioplastics: green and organic waste collection bags, food packaging and containers, plastic utensils (cutlery, glasses, etc.) and some hygiene products (cotton- floppy disks, exfoliating microbeads, ear sticks, etc.), coffee capsules and much more.

Using specific production lines, the compostable packaging industry could become an interesting mechanism for soil fertilization(Ellen MacArthur Foundation, 2016). These specific uses relate in particular to garbage bags for organic waste or food packaging used by fast food establishments, canteens and other closed systems..

To note is that of outmost importance is for the plastics with biodegradable nature is for them to maintain their nature in the marine enviroment, and this is mandatory for all products considered likely to reach any type of water (be it sea, ocean, river, lake etc.) – such products can be tools linked with fishing (fishing nets or lines etc.)

An important economic branch where biodegradable products are used is the cosmetics industry and liquid laundry / dishwashing detergents. Development in this branch is a necessity due to the fact that many components of those are easily discharged through the sewer and without being passed through any waste-water treatment plant it is easy to assume they will end up in various types of waters causing permanent contamination.

Last but not least, industrial, chemical or pharmaceutical packaging areas, among others, may also have an interest in the use of biodegradable bioplastics.

4.5 The need to switch to biodegradable bioplastics

It is necessary to switch to biodegradable and compostable products aiming to bring to a minimun the negative impact on the environment of such products – the most common example si any disposable items with a lifespan of only a few minutes even, yet a lifespan of degradation of at least a few decades. Apart from the long term it takes for them to naturally decompose, there is also the threat of it to end-up in the waters and in turn harm the entire aquatic ecosystem.

The development of environmentally friendly plastic packaging and the fact that the negative effects are significantly reduced, is obviously considerable progress. The ultimate goal is to take out of the circle anything that takes longer time to be naturally decomposed. This is the way to capitalize on the concept of planned obsolescence, in order to obtain from the design phase a plastic to which we can predict the decomposition time (Bruzaud, 2018).

The biodegradable nature of materials comes with endless options for the end-of-life os sucha materaisl, being it through full biodegradabilior or compostability or even turning in biogas through digestion of anaerobic nature. Such bio-based and biodegradable materials are what guarentees us all from the very begining that they will be decomposed in an organic manner (Gontard, 2018).

Ecological and biodegradable organic recovery of bioplastics is in consequence a suitable-like-a-glove solution which can easily and suitably be integrated whne we talke about the end of life for plastics.

But it is naive to be optimistic or to say that biodegradable bioplastics will help solve the problem of ocean pollution with plastic. Because, this is mainly due to the lack of civic spirit. This is primarily a behavioral and waste collection problem, and it is obviously not the biodegradable bioplastic that will solve this behavioral problem.

5. Conclusions

The beauty of the feasibility of this materials come with a higher cost for biodegradable and compostable products when compared to conventional plastics derived from petrochemicals. It's not only about availability only, but it's also all the investement that has to be made along the lines when we talk about factories switching, new reasearch to be financed and all the processes that come along which need to adapt and to go through a costly trial & error period.

However, the savings it generates, as well as improved manufacturing processes and theevolution of the price of oil, tend to make biodegradable and compostable products increasingly competitive vs plastics derived from petrochemicals. Reducing production costs and developing viable economic models are therefore one of the first objectives of research and innovation.

Lookin at the legislation, there is a lack of international legislation to promote or require the use of biodegradable materials from renewable resources. Still, we see some steps, such as those taken by the European Union by adopting the European Directive banning eight disposable plastic products: cutlery, plates, straw, food containers and PES cups, cotton swabs, stirrers and rods from plastic for balloons. Although the Directive has been published, the obligation to use biodegradable plastics for these products as alternatives is not yet implemented.

Today, biodegradable and compostable products are important for the end of life, respectively for composting (household or industrial) or biogas. Their biodegradability allows them, in particular, to integrate into the ecological recovery of the bio-waste industry.

Although this process of recycling organic waste is currently very developed in many European countries, it is still in its infancy in our country, as there is no organized network at the level of territorial administrative units, dedicated to the recovery of organic waste. In order to integrate into an economy of circular organic matter, it is necessary that biodegradable and compostable products no longer reach landfills or incineration. As a consequence, it must be developed urgently in Romaniaa program on waste management - compost component.

It is necessary to inform and educate consumers about the advantages and disadvantages of these products, the need to separate the fractions of compostable waste at source, as well as the responsibility of each for their release into the wild. As for other materials, all solutions considered to reduces plastic pollution is also based on the adoption of virtuous behavior. Raising awareness, educating and informing citizens is at the heart of all policies, in order to better manage the end of life of plastics, in particular to optimize separation at source and packaging collection.

In order to avoid confusion, it is particularly important for users to be able to easily identify biodegradable materials, but also how they can be assessed individually or composted only industrially.

In conclusion, it is important to note that research and innovation in biodegradable materials is particularly strong today. They have been the subject of more than 1,400 scientific publications per year in the last decade (Gontard et al., 2018) . On this subject, research and innovation are progressing and developing worldwide.

6. References

- ADEME (Environmental and Energy Management Agency), 2005. *Biodegradability polymers and biodegradable materials*, synthetic grade I.
- ADEME (Environmental and Energy Management Agency), 2013. *Plastics from bio sources.* ADEME technical sheets.
- ADEME (Environmental and Energy Management Agency), 2015. *Composting, Technical Specifications.*
- Biodeck. Our story, [online] Available at: <https://www.biodeck.ro/> [Accessed 25 May 2020].
- Bruzaud S., 2018. *Innovative materials to limit the impact of plastic on the marine environment.* LorientȘ The House of the Sea.
- Eco Pack. *Biodegradable & Compostable*, [online] Available at: <https://www.envasesecopack.com/> [Accessed 25 May 2020].
- Ellen MacArthur Foundation, 2016. *A new plastics economy, paper presented at the World Economic Forum.*
- Ghiglione J.F., 2018. Plastic pollution of the oceans: how to reverse the situation ? *Observatoire Océanologique de Banyuls-sur-Mer,* [online] Available on: <https://www.obs-banyuls.fr/fr/s-informer/grand-public/conferences/archives-2018/pollution-plastique-des-oceans-comment-inverser-la-donne-5-decembre-2018. htm> [Accessed 22 May 2020].
- Gontard N., Guillard V., Gaucel S., Guillaume C., 2017. Food packaging and innovative ecological action in all their dimensions. *INNOVATIONS agronomic*, 58, pp. 1-9. <Hal-01668195>
- Gontard N., 2018. *Plastic waste: the dangerous illusion of all-recycling*, [online] Available at: <https://theconversation.com/dechets-plastiques-la-dangereuse-illusion-du-tout-recyclage-90359> [Accessed 22 May 2020].
- Gontard N., Guillard V., Gaucel S., Fornaciari C., Angellier-Coussy H., Buche P., 2018. *The Next Generation of Sustainable Food Packaging to Preserve Our Environment in a Circular Economy Context, Frontiers in Nutrition.*
- Hoogzaad J., by Wit M., Ramkumar S. Friedl H., Douma A., 2018. *The circularity Gap Report*
- Plastics Europe. *Plastics Europe Annual Report*, [online] Available at:https://www.plasticseurope.org [Accessed 25 May 2020].
- * * * *Information report - Biodegradable and compostable bioplastic*, [online] Available at: <https://www.sphere.eu/wp-content/uploads/2019/09/18072019-Rapport-SPHERE-ANG-DEF.pdf> [Accessed May 20, 2020].