Novel packaging films and textiles with tailored end-of -life and performance based on bio-based copolymers and coatings

Summer 2023 Newsletter

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BIOnTop Key figures

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Consortium: 21 partners (4 Research and Technology organisations, 9 SMEs, 6 Large Industries, a consumers' association and a pan-European industry association)
7 Biobased Industries
From 8 EU countries

+ Advisory board
+ External Advisory Board
"Dissemination and mobilisation of stakeholders"

Twitter: @BIOnTop_Project **LinkedIn:** www.linkedin.com/in/biontop-project

The BIOnTop project is now closed. This is the last newsletter featuring the achievements of the project and its teams.

The summaries below have been taken from the deliverables which are provided in open access, for dissemination to the broader public.

Over 4 years, BIOnTop has developed **novel bio-based and compostable packaging and textiles** through **experimental research on copolymers and compounds with customized biodegradability and multifunctional coating solutions**.

BIOnTop has gathered 170 experts from research institutes, the mechanical engineering sector, food and packaging companies, and trade bodies from eight European member states.

Features on BIOnTop results and collaborations

Feature 1: Testing BIOnTop packaging demonstrators for suitability for home composting, industrial composting, and anaerobic digestion (D4.7).

OWS Research Foundation tested and evaluated the suitability of the developed packaging to be treated via home composting and anaerobic digestion.

BIOnTop demonstrators show additional functionality and processability of PLA, thereby unlocking new product types that can be produced. The current production of the additional materials in the product formulations requires further optimization to be able to achieve environmental impacts as low or lower than the reference systems. Across all the demonstrators investigated, the tea bags, whether uncoated or coated, appear to have the most promising results.

Fig. 1: Some of the BIOnTop demonstrators, the tea bags, the net and the trays.

Home compostability tests: To be home compostable a product must fulfil the requirements of the European standard *EN 13432 Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging (2000)* with a demonstration of biodegradation and disintegration at ambient temperature.

This specific testing program is applied in the certification schemes of OK compost HOME of TÜV AUSTRIA and the DIN Geprüft HOME COMPOSTABLE logo of DIN CERTCO. TÜV AUSTRIA (formerly Vinçotte) is a certification body authorized by European Bioplastics to award the Seedling logo to products compliant with EN 13432. By awarding both the OK compost INDUSTRIAL and the Seedling logo, TÜV AUSTRIA's certificate holders have a way to give recognition to their compostable products throughout the entire European market.

The focus in BIOnTop was on biodegradation and disintegration as these are the most difficult parameters to fulfil. All developed products are PLA (polylactic acid) based, making it a challenge to obtain home compostable products, as PLA normally needs a thermal trigger before hydrolysis and biodegradation start.

Fig.2: DIN Geprüft HOME COMPOSTABLE logo of DIN CERTCO

Fig. 3: OK compost HOME of TÜV AUSTRIA

Based on PLA, the BIOnTop developed tea bag yarn and tray (± 0.42 mm) are **home compostable.** However, the film and oriented net could not demonstrate sufficient degradation under these conditions.

Fig. 4: Disintegration of the alginate-coated PLA-based tea bag after 12 weeks of home composting.

Anaerobic digestion: For anaerobic digestion, there is no specific standard nor has a testing scheme been developed by a certification institute. Still, OWS has developed a draft proposal for such a scheme and testing was performed according to this scheme. The biodegradation and disintegration under dry thermophilic (52°C) and mesophilic (37°C) anaerobic conditions were considered as these packaging products are eventually more likely to be included in the organic fraction of municipal waste and treated in "dry" systems opposed to wet anaerobic conditions. Also, mesophilic conditions were considered as one of the objectives of the project was to develop PLA products that are also degradable under mild conditions.

None of the developed demonstrators (the yarn was not evaluated under these conditions, but similar behaviour was expected) showed sufficient degradation under anaerobic conditions. They cannot be treated in bio-gasification plants. However, organic recycling via **industrial composting** is an option for all products.

Link to the Deliverable: D4.7 LCA (Life Cycle Assessment) and organic recycling of packaging by home composting and anaerobic digestion, Zenodo: https://zenodo.org/record/8220455

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Feature 2: What do consumers think of biobased packaging?

Consumers are the key actors of the BIOnTop applications: An analysis of their needs and perception was carried out by the Movimento Consumatori, of the major Italian consumers' associations, with interesting results.

Movimento Consumatori analyzed the consumer perception of biobased packaging, identifying their stage of awareness, their attitudes, and their willingness to buy. The survey collected 3.303 responses collected in eight European countries: Germany, France, Italy, Spain, Netherlands, Belgium, Greece, and Malta. Additionally, the survey involved three focus groups focused on consumer associations, food-chain industry companies and institutions. Consumer associations, in partnership with producers and retailers, can play a key role in leading the green transition process from traditional plastics to bioplastics. R&D projects like BIOnTop need to unlock consumers' potential through measures that empower, support, and enable every consumer to play an active role in the green transition.

Some key results emerging from the survey need to be considered for future activities in research and development:

- '*Bioplastics'* is a term recognized by about 2 out of 3 people, but its meaning is not entirely grasped, meaning that people do not properly understand the features of nature of the bioplastics' materials.Experts use the term *'bioplastics'* in diverse ways i.e., public institutions point out to biobased, biodegradability, and end-of-life treatment aspects, whereas manufacturers mostly refer to compostability characteristics.
- Communication targeting the public should be aimed at increasing the desirability of bioplastics and stimulating the demand from the consumer side. Such communication could be aimed at the public through dedicated campaigns and reinforced through detailed information regarding each product's labels. Bioplastics should be better defined and presented to allow people to know how to deal with them. Bioplastics should not just be easily identifiable, but their production should also be traceable to reassure green consumers that each step of the packaging process does not harm the environment. Improved communication is needed to ensure consumer compliance with waste disposal instructions, given their significant impact on the overall waste management system and the costs for both producers and consumers.
- Municipalities and consumer associations prefer "greener" plastic and have fewer concerns regarding the more widespread use of bioplastic packaging. Many adults – mostly those over 56 and the more educated – believe in bioplastics' benefits in protecting the environment.
- Bioplastics producers are more comfortable considering bioplastics as a tool that can contribute to a more sustainable economy but cannot completely substitute fossil-based plastics.

More information about consumer perception can be read in the BIOnTop deliverable D7.5 and the full set of data is available on Zenodo: Avanzati Tiziano, & Zanutto

Alberto. (2021). Interim report on BIOnTop value chain and consumer perception - raw data [Data set]. Zenodo. https://doi.org/10.5281/zenodo.4772351

Link to the Deliverable: D7.5, Final report on sustainable business models and value chains including consumer perception aspects, Zenodo: https://zenodo.org/record/8220496

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Feature 3: Potential and expected benefits of the BIOnTop materials through their tailored end-of-life possibilities.

The interpretation of the end-of-life impacts and whether one is more environmentally friendly than the other is often obscured by the large variety of scope and depth between different studies. Mechanical recycling often comes out as the option with the lowest impact on the environment, especially when recycling in a closed loop is possible. Unfortunately, in the field of food packaging, and even for well-established recycling routes, such as exist for PET, closed-loop recycling is only possible for a part of the incoming waste and for a limited number of times. It is more probable that the waste is recycled in an open recycling route which means that the recycled material has lower processability than virgin plastic material and is subsequently used for other applications.

Regardless of whether an open or closed loop is considered, the main impact benefit of mechanical recycling lies in the fact that two functions are fulfilled at the same time: waste is removed, and new raw material is produced. The impact benefit depends for a part on the application of the recycled material and the material it replaces on the market.

Does recycled material replace virgin grade plastic granulate or does it replace other materials?

If recycled granulate can replace virgin-produced plastic (possibly in a closed-loop system) relatively large impact benefits can be expected, if transportation and electricity use related to the recycling process (and subsequent distribution) are not excessive. If the recycled material replaces other materials, then it depends on the type of replaced material and intended application. Note that recycled plastics are often used in items that don't require virgin plastic quality in the first place. Recycled plastics may also be used in items with relatively long lifetimes (gardening or decorative items), although these lifetimes are mostly not long enough to be interpreted as true carbon sinks. Just as with fossil-based plastics, the processability or usability of the recycled bioplastics should be maximized as otherwise, high-end applications will still require virgin-grade materials and the potential environmental benefits of mechanical recycling will not be used to the full extent.

Experiments done in BIOnTop have shown that granulates from the recycling of BIOnTop lidding films retain very good processability characteristics and may even be suited for closed-loop recycling. **Granulates from recycled BIOnTop**

trays had decreased properties but could still be used for downgraded applications. On the other hand, these trays showed advanced biodegradability under home composting conditions (see further).

As indicated higher, **composting of plastic packaging** is interesting when this packaging is spoiled with biowaste such as food waste. Food waste is not suited for incineration because of the relatively high moisture content and subsequently only limited energy can be recovered in this route. Also, landfilling of food waste is not desirable because the anaerobic conditions will lead to methane production. While this methane can be recovered with specialized techniques at some locations, any leakage of this powerful greenhouse gas cannot be prevented. Composting allows the recovery of a part of the carbon in the waste as compost, of which subsequently a part will enter the soil system as humus while the other part will be converted to CO_2 upon application to the soil. Compost as a soil conditioner has the benefit that it can be used to replace peat, which is considered a fossil fuel, and which also is less effective for humus formation. Apart from this, compost improves the structure and health of the soil by adding organic matter, helps the soil retain moisture and nutrients, attracts beneficial organisms to the soil and reduces the need for pesticides and fertilizers, reduces the potential for soil erosion and builds resiliency to the impacts of climate change. Characteristics that are not yet recognized in life cycle analyses. Furthermore, if the composting process is performed under good conditions (oxygen-rich, suitable humidity), the emission of environmentally harmful gasses such as methane, dinitrogen oxide and ammonia should be limited. Note that methane and dinitrogen oxide are much more powerful greenhouse gasses than CO_2 and that ammonia is a major impact contributor directly or indirectly to all N-related environmental impacts such as acidification, eutrophication, and fine particulate matter formation. The big benefit of industrial composting lies in the fact that the composting process is optimized (to the extent possible) in **industrial composting** facilities, thereby lowering the residence time while at the same time maintaining compost quality.

These optimal conditions are much harder to achieve when **composting at home.** Consequently, harmful emissions of methane, dinitrogen oxide and ammonia are much more likely to occur at home composting. The benefit of home composting, namely the lack of waste transportation, thus is counteracted by the emissions caused by the suboptimal conditions that are much more likely to occur at home composters than in industrial composting facilities. However, it is exactly here at home composting, where a potential exists for compostable bioplastics. Effective composting not only depends on factors such as oxygen availability and humidity but also on the C: N ratio of the waste. A good composting condition would require a C: N ratio of 20 to 40. Kitchen waste and food waste generally are high in N and low in C. Plastics, in contrast, consist for the largest part of C and, if they are (home) compostable, may be very effective in increasing the C: N to a more favourable ratio, especially at home composting where composting parameters are not monitored. Compostable plastics may also be used to tune the C: N ratio in industrial composting facilities, although suitable C: N ratios are usually already achieved by other C-rich materials such as straw and wood pellets. It is not straightforward to assess how the environmental impact of the (industrial) compost will change when straw or wood is replaced by these compostable plastics. Furthermore, compostable plastics are sometimes criticized that they do not contribute to the formation of compost (and humus) and thus carbon storage. The C stored in the compostable plastics is indeed much more likely to be

used as an energy source by the composting bacteria, and therefore this plastic-C would rather be converted to CO_2 than as C stored in humus. However, without an energy source, bacteria won't be able to grow in biomass and as such it influences positively the composting process. Furthermore, when these plastics are used for packaging organic matter (food, feed...) it will allow a more easily disposal to the green fraction and bring more organic waste to the composting facilities, diverting it from incineration or landfilling, and as such inducing environmental benefits. Furthermore, for biobased materials, as developed within the BIOnTop project, composting is a circular process and as such part of a more sustainable economy.

The environmental impact of the composting process will also depend on the type of product that is considered. Tea bags, for example, are usually disposed of together with their wet organic contents and generally are incinerated. Because of the high moisture content, transportation of waste tea bags is relatively inefficient, and only little energy can be recovered when this wet waste is incinerated**. In BIOnTop, tea bag textiles are developed which are compostable at the industrial level or home. Given the relative inefficiency of transportation of the relatively heavy wet waste, home composting of tea bags may be a sustainable option provided that good composting conditions are maintained in the home composter. The high C content of the bioplastic may play a role in obtaining good composting conditions. Apart from these tea bag textiles, also biobased home compostable trays were developed, unlocking the potential for composting plastics at home, and at the same time improving the composting of the other biowaste.**

Furthermore, these tea bags and trays are also industrially compostable, as the developed biobased films and oriented nets for food packaging. This will result in a higher biowaste capture for spoiled food, as the packaging can be treated together with its content. This is an indirect effect of these compostable packaging but will divert organic waste going to incineration and instead be recycled into valuable compost. Together with the high biobased content of the developed materials and the additional option to also mechanically these products, it will result in a more sustainable world.

Link to the Deliverable: D7.8 on Zenodo https://zenodo.org/record/8220631

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Feature 4: BIOnTop results as examples of the transition to a climate-neutral bioplastics economy.

The transition to a climate-neutral plastics economy requires a shift towards non-fossil bio-based plastics in addition to efforts to rethink, reduce, reuse, and recycle. BIOnTop results are outstanding examples of how this transition can be achieved and how the technical specifications of the applications can make it possible to shift to bio-based plastics. The packaging applications developed in BIOnTop have been demonstrated to be:

● Close to 100% bio-sourced.

● Providing superior product preservation in case of barrier packaging and advanced functionalities.

● Meeting converters' processability (standard techniques used).

● Meeting the requirements of a wide range of product demonstrators and the perceived needs of the consumers.

● Recyclable-by-design/ end-of-life options adjustable to the respective applications (e.g. mechanically recycled, industrially/ domestically composted, suitable for anaerobic digestion).

● Cost competitive.

● Enabling a reduction of end-of-life handling fees.

● Having a reduced environmental impact.

BIOnTop applications are a demonstration of how eco-design for packaging products is not only technologically feasible but also economically viable. The project has designed novel functional bio-based packaging products that are reusable, recyclable, and/or compostable and biodegradable, as an alternative to the currently identified benchmark products. The novel packaging products are recyclable or compostable/ biodegradable in various environments and can reduce their overall environmental footprint. A more circular packaging production is possible. The benefits of circular packaging production are tangible, and this has been demonstrated by the development of novel processing solutions and products.

At its final conference, held together with other 11 EU-funded projects, the BIOnTop consortium has also highlighted the following areas of improvement for the future:

● More work is needed to assess and reduce the net greenhouse gas emissions of bio-based plastics compared to their fossil-based equivalents, considering the lifetime of the application and the possibility of multiple recycling.

● The biodegradation processes need to be further explored to ensure that bioplastics can biodegrade safely, considering the possible transfer to other environments,

biodegradation timeframes and long-term effects, and to minimize any negative effects, including long-term effects, of additives used in biodegradable and plastic products.

● More research is also needed into consumer behaviour and the claims of biodegradability as a factor that may influence littering behaviour.

Link: Proceedings of the Conference "Innovations on Sustainable Materials for Textiles, Coatings, Films, and Other Wide Use Applications" https://doi.org/10.5281/zenodo.7944891

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Recent peer-reviewed publications and conference proceedings

Recyclability studies on Poly(lactic acid)/poly(butylene succinate-co-adipate) (PLA/PBSA) biobased and biodegradable films

Coltelli, M.-B., Aliotta, L., Fasano, G., Miketa, F., Brkić, F., Alonso, R., Romei, M., Cinelli, P., Canesi, I., Gigante, V., Lazzeri, A., Recyclability Studies on Poly(lactic acid)/Poly(butylene succinate-co-adipate) (PLA/PBSA) Biobased and Biodegradable Films. Macromol. Mater. Eng. 2023, 2300136, https://doi.org/10.1002/mame.202300136

Macromolecular Materials and Engineering Open Access

Research Article | Open Access

Poly(lactic acid)/poly(butylene succinate-co-adipate) (PLA/PBSA) blends are found promising for film packaging applications because of their flexibility, resistance, and compostability. Industrially extruded granules and films based on PLA and containing different amounts of PBSA are reprocessed through mini-extrusion, to simulate recycling, and tested in terms of their melt flow rate as a function of PBSA content. Moreover, pure PLA commercial granules and the film produced extruding the PLA/PBSA 60/40 blend are reprocessed several times by injection moulding and characterized in terms of melt flow rate, mechanical properties, thermal properties, and colour as a function of injection moulding cycles. The variation in melt fluidity and thermo-mechanical properties is negligible in up to 3 injection moulding cycles for both pure PLA granules and PLA/PBSA blend. In the case of blend the color change (yellowing and darkening) is more evident and slight local compositional change in injection molded items can be evidenced as well as a slight decrease in PBS

crystallinity as a function of injection molding cycles. Nevertheless, in applications where these aspects are not critical, these materials can be recycled by extrusion or injection moulding before being composted, thus prolonging their life cycle, and storing carbon in them as longer as possible.

Biobased Polymers for Environmental Applications

Andrea Lazzeri, Maria Beatrice Coltelli and Patrizia Cinelli
ISBN 978-3-0365-7669-5 (hardback)
ISBN 978-3-0365-7668-8 (PDF)
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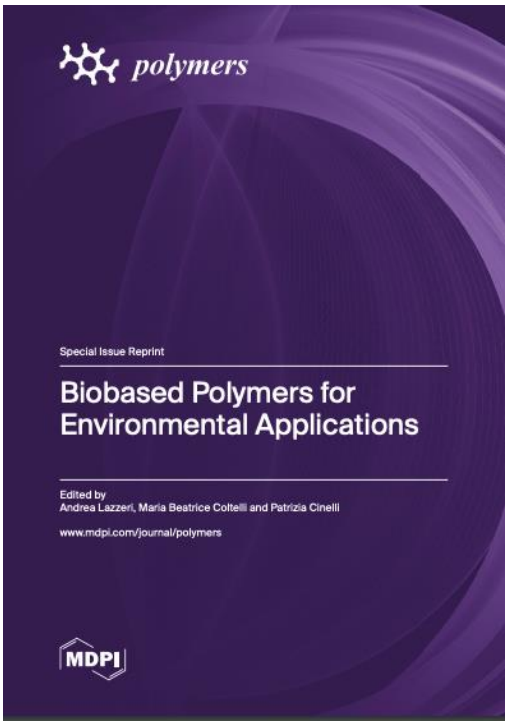

Micromechanical analysis and fracture mechanics of Poly(lactic acid) (PLA)/Polycaprolactone (PCL) binary blends

Laura Aliotta, Vito Gigante, Ruben Geerinck, Maria-Beatrice Coltelli, Andrea Lazzeri
Polymer Testing, Volume 121, 2023,107984,
ISSN 0142-9418

https://doi.org/10.1016/j.polymertesting.2023.107984
(https://www.sciencedirect.com/science/article/pii/S0142941823000648)

Abstract: Poly(lactic acid)/polycaprolactone (PLA/PCL) blends have been studied in the literature, but the deformation mechanism that is related to the toughness increment concerning pure PLA has not been investigated in detail. The novelty of this work is to understand in depth the correlation between the micromechanical deformation processes occurring in PLA/PCL blends to the micromechanical properties, their morphology, and their fracture mechanism. PLA/PCL blends containing increasing amounts of PCL (from 10 up to 40 wt%) were produced. A novel characterization approach, not yet investigated for these blends, was carried out by dilatometric uniaxial tests using a video extensometer. The shape of the dilatometric curves coupled with SEM analysis revealed how changing the PCL amount different concurrent micromechanical deformation processes occurred. When 10 wt% of PCL was added only particles debonding occurred leading to lower enhancement of elongation at break; at 20 wt% both debonding and voids growth along the tensile direction occurred, while at 40 wt% of PCL shear yielding was predominant that lead to a great enhancement of the elongation at break. The PLA/PCL blends' capability to absorb energy at a slow rate, was evaluated by the elastoplastic fracture approach based on the ESIS load separation criterion. The results obtained were then correlated with the final blend morphology.

Proceedings of the Conference: Innovations on Sustainable Materials for Textiles, Coatings, Films, and Other Wide Use Applications

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Düsseldorf, 11 May 2023, in-person and online

Organised by European Bioplastics, ENCO Consulting and AIMPLAS.

All the videos of the conference are on YouTube:
https://youtube.com/playlist?list=PL55WHEvTORx6wv4fSUaWOpJWHfcF_7cp5

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All our presentations and posters are uploaded to Zenodo for granting you all Open Access, long-term, extending the life of the results well beyond the lifetime of the project. Have you already checked what is available on Zenodo?

https://zenodo.org/communities/biontop/

BIOnTop Tech watch

For other relevant news, have a look at the BIOnTop tech watch

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