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Innovations on Sustainable Materials for Textiles, Coatings, Films, and other Wide Use Applications

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In-person and online

INNOVATIONS ON SUSTAINABLE MATERIALS FOR TEXTILES, COATINGS, FILMS AND OTHER WIDE USE APPLICATIONS

Conference 11 May 2023

biontop
USABLE Packaging
MANDALA
CelluWIZ
POLYBIOSKIN
nenuPHAr
REPurpose
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About this document

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This event has been organized by the BIOnTop project partners:

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About BIOnTop

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Foreword

europeanbioplastics
Hasso von Pogrell
Managing Director

While modern economies highly depend on plastics in Europe with consumes in the range of 50 million tons per year, only 25-31% of the plastic waste in Europe is currently recycled and the larger share is incinerated or even landfilled (high variability between countries). We still landfill nearly 40-50% of plastic waste[1]. Today, in Europe 70% of the packaging used in a wide variety of applications in different market sectors – including food, pharmaceuticals, and clothing – is not recyclable. It consists mostly of multi-layer packaging, with each layer composed of different polymers that perform specific functions, making it technically non-recyclable. The end-of-life phase for this packaging, therefore, is either incineration or landfill.

Moreover, the compostable bio-based packaging that is currently available mainly ends up in industrial composting facilities. This is because other biological waste treatment processes like anaerobic digestion and home composters are generally not suitable for most of the current compostable polymers.

In the past few years several projects funded by the Bio-based Industries Joint Technology Initiative such as BIOnTop, CelluWiz, MANDALA and USABLE PACKAGING and many others featured in this conference proceedings, have developed novel alternative solutions to 'eco-design' packaging products to avoid the incineration and landfill routes at their end-of-life phase, rerouting them instead towards approved and accepted applications, where they can add value without adding an environmental burden.

In 2018, the consortia of the projects BIOnTop, CelluWiz, MANDALA and USABLE PACKAGING responded to a call of the Bio-based Industries Joint Undertaking /European Commission related to the development of bio-based packaging products that are biodegradable/ compostable and/or recyclable.[2]
The specific challenge of these twin projects was to make the end-of-life phase for packaging significantly more sustainable.

Over the years, the projects have designed new processing systems for functional bio-based packaging products that are reusable, recyclable, and/or compostable and biodegradable, as an alternative to the currently identified benchmark products.
The projects addressed the production process, including the necessary improvements to lamination and coating steps to obtain the target end-products and their specifications.
Within their lifetime, the projects have proved that the target packaging products are recyclable or compostable/ biodegradable in various environments to reduce their overall environmental footprint. This has made their production and use more circular.

1 https://www.europarl.europa.eu/news/en/headlines/society/20181212STO21610/plastic-waste-and-recycling-in-the-eu-facts-and-figures and https://www.oecd.org/newsroom/plastic-pollution-is-growing-relentlessly-as-waste-management-and-recycling-fall-short.htm

2 BBI.2018.SO3.R10 - Develop bio-based packaging products that are biodegradable/ compostable and/or recyclable

The challenge also addressed multi-layer products: The twin projects considered the feasibility of producing multi-layer/single-polymer solutions, and ensured that the required functionalities and outperform state-of-the-art alternatives for sustainability were met.

Along with the environmental sustainability of the developed solutions, other factors – such as innovation in functionality and production – were considered in these proposals. Any potential hazards associated with the developed processes and products were analyzed to ensure that the products comply fully with REACH legislation[3] and other toxicity requirements, safety requirements and any relevant EU legislation.

The industry actively participated in the consortia, and demonstrated the potential for integrating the developed concepts into current industrial landscapes or existing plants so that the concepts can be deployed more quickly and scaled up to apply industrial-wide.

These projects have specifically demonstrated the benefits versus the state-of-the-art and existing technologies, by providing evidence of new processing solutions and new products obtained, by involving consumer organizations, together with recyclers and composting plant representatives. Their commitment to assessing the environmental impacts of the developed processes or products has been demonstrated by using LCA methodologies based on available standards, certification, accepted and validated approaches. In some of these projects, e.g. in BIOnTop, the teams have also included pre- and co-normative research necessary for developing the needed product quality standards.

All in all, these projects have also included an economic viability performance check (e.g., value chain and market analysis) of the developed products and processes, along with an analysis of social impacts where applicable.

We are excited to share with you today the results of these projects and many others focusing on innovative solutions for wide applications.

3 The Regulation for Registration, Evaluation, Authorisation and Restriction of Chemicals, effective since 1 June 2007.

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

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The plastic shopping bag we use today was invented in 1965. By the 1980s, the plastic bag revolution was in full swing with grocery and department stores around the world using them. It was a simple decision since plastic bags are stronger and cheaper compared to paper. Reducing plastic bag use is a priority for the EU today.

The EU-funded BIOnTop project helps shape the future of the plastics sector via recyclable-by-design cost-competitive packaging solutions. The packaging is made from renewable resources and will be biodegradable in home-composting conditions as well as recyclable for secondary packaging.
Only 31% of plastic is currently recycled and plastic packaging still has a deficient end of life. Thus, improvements are needed to provide cost effective solutions with high bio-based contents and suitable performances for demanding packaging applications, with a consumption of 19 million tons per year, while still achieving compostability in mild conditions.

Using sustainably sourced comonomers, additives and fillers to formulate novel PLA copolymers and compounds, BIOnTop delivers recyclable-by-design cost competitive packaging solutions that can be mechanically recycled, industrially/home composted or even suitable for anaerobic digestion.

Moreover, the barrier properties of delivered bio-packaging trays, films and derived packaging, will be enhanced using removable protein-based coatings and a novel fatty acid grafting technology to decrease permeability and compete with fossil packaging.
In the field of textile packaging, most used coatings are not bio-based and of different nature from the coated fibers, making material or organic recycling extremely difficult. New PLA coatings or fatty grafting will allow reprocessing without significant loss of properties.

BIOnTop packaging, based on >85% renewable resources, is compatible with a broad range of packaging applications' requirements but also multiple end of life options. Our materials are biodegradable in home composting conditions, but also recyclable for multiple use secondary packaging.
Based on new circular bioeconomy value chains, BIOnTop generates growth for EU bioplastics and end users' industries in the food and personal care sectors with potential in many fields. All in all, reducing the environmental footprint of plastics, our new bio-based packaging will have a significant positive social and environmental impact.

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Twin project: Celluwiz - Production of all cellulose packaging fully recyclable and biodegradable using two combined processes: MFC wet lamination and chromatogeny grafting

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Keywords: All cellulose packaging, MFC wet lamination, Chromatogeny grafting.

Food packaging industry is looking for alternatives to petrobased products focusing on biobased, biodegradable and recyclable solutions without deteriorating the barrier performances.
In the framework of the CelluWiz[1] European project, three proofs of concept of cellulosic packaging (clamshells, cups and trays) have been produced using two processes: the wet lamination with Micro Fibrillated Cellulose (MFC) of a board followed by the chromatogeny grafting.

MFC are known to bring a barrier to grease, oxygen and contaminants. A thin layer of MFC was then applied on a board without the use of glue using the MFC wet lamination process[2] at pilot scale. In order to confer water and water vapor barrier properties to the MFC laminated board, reels were treated by chromatogeny[3] also at pilot scale.

Barrier properties
All cellulose barrier material with good barrier properties was finally obtained as detailed in the table below.

Material	$Cobb_{60}$ water [g/m²]	Kit test	OTR [cm³/(m².d.bar)] 23°C, 50%RH
MFC wet lamination and chromatogeny grafting	16.4	11	<5

End of life

Regarding the end of life, the produced materials have been proven to be fully recyclable (EN13430): easily disintegrated, very low amount of rejects, good visual aspect of the recycled materials and no tackiness effect. The Celluwiz materials are also fully biodegradable according to the EN 13432:2000 + ISO 18606:2013 standard (good biodegradation, disintegration and good compost quality).

Production of PoCs

The MFC wet laminated chromatogeny grafted reels were then converted in cups, clamshells and trays by the Celluwiz partners as observed in the picture below. Specific converting conditions were required for each proof of concept. Finally, the proofs of concept demonstrate that the material produced have an applicability in a range of industry relevant applications.
This presentation will focus first on the concept of the Celluwiz project, the presentation of the two processes and the performances of the materials produced. Finally, the presentation will highlight the production of the proofs of concept.

Acknowledgments: CelluWiz project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 838056.

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Twin project: MANDALA - A sustainable future for multilayer packaging

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Keywords: packaging, multilayer packaging, recycling

Plastic recycling is a major technological challenge. Currently, the world recycles only 14% of the plastic packaging it uses and 72% is not recovered at all: 40% is landfilled and 32% leaks out of the collection system. Despite having an inherent value, virtually all -95%- is simply lost after a single use.

The MANDALA project presents a sustainable solution for the plastic packaging sector, focusing on 3 fundamental pillars: eco-design, adhesives with double functionality and end of life, with the aim of finding a sustainable and effective solution for multilayer packaging in the medium term, insofar as recycling the conventional materials as well as the use of biopolymers.

The presentation will focus on presenting the work carried out in Mandala:

- Developed bioplastics with enhanced barrier properties
- Dual functionality adhesive
- Delamination tests and barrier properties

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Twin project: USABLE PACKAGING - Unlocking the potential of Sustainable BiodegradabLe Packaging

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Keywords: Packaging, Organic Recycling, Polyhydroxyalkanoates, Biodegradable, Compostable

Plastic packaging materials have become ubiquitous. They are widely used in the food and beverage, healthcare, cosmetics, consumer goods and home and garden industries. Most plastics start with hydrocarbons from crude oil. The USABLE PACKAGING project turned that process on its head by developing biomass-based, biodegradable raw materials from food processing streams. The technologists and companies involved in the project applied those materials to produce polyhydroxyalkanoates-based new organic recyclable packaging that rivals conventional petrochemical-based ones in technical characteristics and performance.

USABLE PACKAGING has developed high performance plastic packaging through a sustainable and fully circular value chain, where the biomass raw material sourcing derives from food processing side streams, to obtain, via a low footprint biochemical processing, a portfolio of bio-based biodegradable building block materials enabling the realization of complex packaging structures, including laminates and multilayer films, to match key functional requirements of commercial petrochemical plastics, such as gas/ liquid barrier properties, mechanical resistance, cold temperature resistance, hot tack, among others, while enabling the realization of a full set of packaging items from rigid to semi rigid and flexible by tuning the functionalization of base resins through biosynthesis and the compound processing. USABLE PACKAGING concept has been designed to retrofit the existing state of the art packaging processing technology by controlling the chemical and physical properties of the base building blocks materials. With respect to petrochemical peers USABLE PACKAGING has managed to offer a sustainable end-of-life, since on one hand materials are biodegradable with no harm to the environment, on the other hand they have potential to deliver additional economic value through organic recycling for production of biogas, with the same consolidated disposal route as bio-waste, or through biotech recycling, to be used again as feedstock for the production of the same base resins for USABLE PACKAGING, basically closing again and again the same value chain to re-obtain virgin materials.

Acknowledgments: USABLE PACKAGING project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 836884.

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Website: https://www.usable-packaging.eu/

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Success Story: POLYBIOSKIN - High performance functional bio-based polymers for skin-contact products: plasticized bionanocomposites films

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Keywords: PLA, PBS, PBSA, bionanocomposites, diaper, chitin nanofibrils, carbonate

Introduction

Replacing petroleum-based materials with renewable biodegradable counterparts is a good strategy for taking care of the environment, considering both sources and end of life related best practices in view of boosting the application of circular economy principles. PolyBioSkin developed skin-contact biopolymer-based products with increased performance and functionality, such as diapers, cosmetic pads and wound dressings, exploiting environmentally friendly innovative technologies for the preparation of substrates and for the functional modification of their surface.

Poly(lactic acid) (PLA), fully renewable and compostable, has enormous potentialities for application in contact with the skin in the diaper sector, as well as in other cosmetic or biomedical applications involving skin contact (1). These potentialities are strongly linked to the possibility of processing it to obtain flexible films by means of flat die extrusion. The plasticization of selected polymeric blends, obtained by using biobased additives (2), is the strategy followed to obtain materials with the suitable mechanical properties and a maximized renewable content. It was noticed a tendency of films to slowly partially release plasticizer, negatively affecting surficial stickiness and oiliness of films. The addition of calcium carbonate (3) and other bionanofillers like chitin nanofibrils (4,5) can allow surficial properties of films to be modulated. The addition of inorganic fillers as well as chitin nano-fibrils, having different surface to volume ratio and morphology, was investigated as a possible strategy to limit this issue.

Experimental

The raw materials used in this work were: PLA 2003D Ingeo (NatureWorks), Poly(butylene succinate-co-adipate) (PBSA) bioPBS (Mitsubishi), acetyl-tri-n-butyl citrate (ATBC) (Tecnosintesi), nano calcium carbonate HAKUENKA CCR (OMYA), micro calcium carbonate

OMYACARB 2AV (OMYA), chitin nanofibrils (MAVI), Plastistrength 550 (ARKEMA, melt strength regulator).
The extrusion of the PLA 2003D with bioPBS, ATBC, Plastistrength 550 and different additives (nano calcium carbonate, micro calcium carbonate or chitin nanofibrils) at different concentrations was carried out using a TwinLab II Haake ™ Rheomex CTW 5 laboratory screw extruder. The extrusion was carried out at 190 ° C and 110 rpm for one minute. After extrusion, the recovered materials were compression molded to obtain films of about 100 micron in thickness. Films of selected formulations were prepared by flat die extrusion using a COMAC EBC 25 HT twin screw semi-industrial extruder equipped with a flat die extrusion accessory.
Three square specimens of films of each formulation, kept in a ventilated oven at 60°C to accelerate the process, were weighted as a function of time to determine for each formulation the average loss of ATBC. Tensile tests (UNI EN ISO527) were carried out using a universal INSTRON 5500R test machine with a 100 N load cell at a speed of 100 mm/min. Morphological investigations by SEM were carried out using a FEI Quanta 450 ESEM FEG field emission instrument.

Results and Discussion
Thanks to POLYBIOSKIN an electrospun biobased beauty mask (6) and wound dressing were developed containing anti-microbial, antioxidant and anti-inflammatory molecules. A fully biobased diaper was also realized, designing a PLA based top-sheet and a cellulosic based superabsorbent (7) (Figure 1).

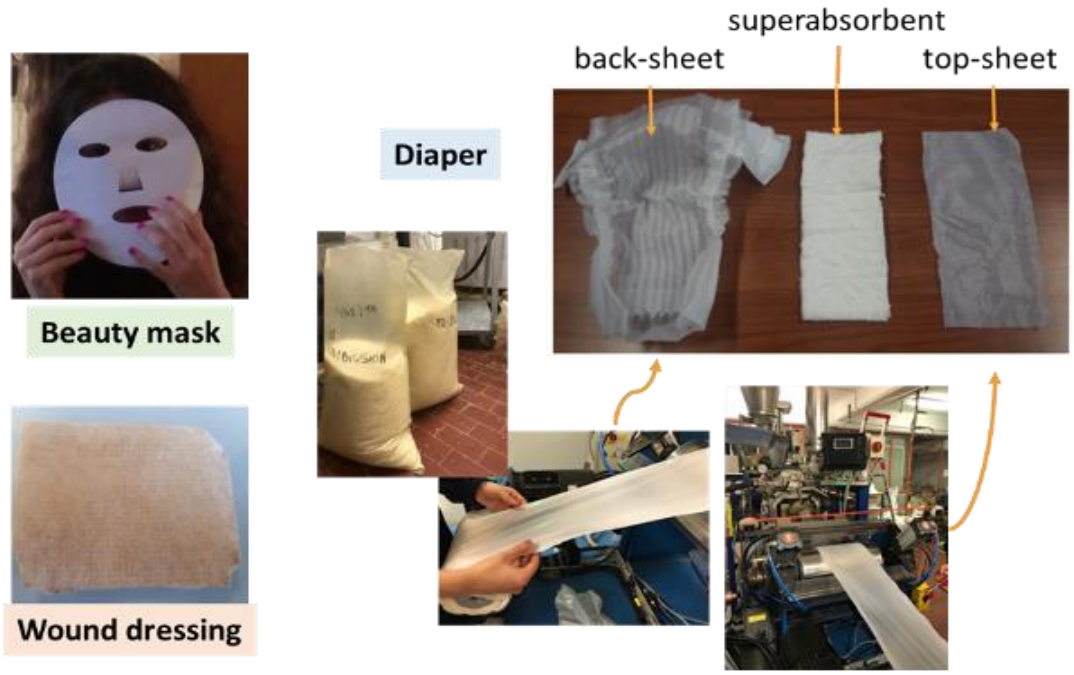

Figure 1: *Prototypes of beauty mask, wound dressing and diaper.*

Regarding the PLA based top-sheet for the diaper application, preliminary studies in the laboratory were performed by the INSTM/UNIPI partner. PLA was blended with biobased polyester and plasticizer. The selected plasticizer was acetyl tri-n-butyl citrate (ATBC) (2). The addition of calcium carbonate and chitin nanofibrils did not modify significantly the tensile

properties of films with respect to the reference blend and its compatibility with cells. On the other hand, it was found that the weight loss of ATBC was much decreased by adding calcium carbonate. Nano carbonate showed good potential to reduce ATBC loss but it was found that in the condition of extrusion it could not be dispersed at a nanometric level. Data demonstrated that the weight loss decreased by adding calcium carbonate or chitin nanofibrils (8). Hence this strategy resulted promising to control the surficial oiliness of films without changing significantly their mechanical performances. The production of biobased and biodegradable functional top-sheets was up-scaled in the framework of the project, then prototypes including the cellulosic based superabsorbent were produced. These diapers, more beneficial for skin and environment than fossil counterparts, showed properties much similar to them.

Conclusions

POLYBIOSKIN results attracted the interest of several companies involved in the sanitary, cosmetic and biomedical sectors. African and Asian associations and entities were interested in the biobased and biodegradable features of the products for solving their specific waste management issues. Training activities, carried out through the use of the project website in the pandemic period, attracted students and scholars. Many papers and a book were published regarding the scientific topics and findings of the POLYBIOSKIN project.

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Success Story: SEALIVE - Strategies of circular Economy and Advanced bio-based solutions to keep our Lands and seas alive from plastics contamination

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Sustainable business models to design advanced bioplastics solutions

Europe's efforts to reduce plastic pollution on land and in the sea aim for sustainable business practices, compatible with the principles of the circular economy. Consequently, the use of organic materials (bioplastics) or degradable materials (biodegradable) is encouraged. The EU-funded SEALIVE project proposes advanced circular strategies that prevent and substantially limit pollution. This solution will be tested in Cyprus, Denmark, France and Ireland. It will be developed under recycling, biodegradability and composting norms for advanced systems. The project aims to develop circularity techniques and end-of-life solutions that will support sustainable bio-based plastics solutions. The solutions will be tested in eight cases representing high pollution potential for land and sea.

SEALIVE aims at demonstrating innovative circular strategies for bio-based plastics in land and sea applications. The project will be driven by economically and technically sustainable business models based on materials with advanced properties, design for circularity techniques and end-of-life solutions. It will establish a partnership of raw material providers, convertors, end users, recyclers, policy experts, certification organizations and NGOs to demonstrate solutions within a shared vision for circular plastic strategies. Solutions for reusable, recyclable and biodegradable bio-based plastics to prevent and significantly reduce marine pollution of all kinds will be demonstrated in four pilot territories.

Innovative formulations based on PHAs, PLA and starch materials with advanced properties will be developed following recycling, biodegradability (marine and land) and composting standards. Design for circularity techniques (recyclable multi-layer single packaging materials, digital materials for traceability) and End-of-life solutions (high precision NIR-based mechanical recycling, controlled biodegradation/composting in natural and industrial conditions) will be upscaled at TRL6.

Solutions will be applied to 8 end-applications with high potential for pollution reduction of soils and water media: rigid food containers, flexible packaging, agricultural films, fish crates, fishing nets and aquaculture mesh bags. Pre-normative research will be carried out to improve current standards for biodegradation, composting and recycling with regards to eco-toxicity, safety, and influence of plastic aging. Policy recommendations at EU and global level will be provided to build a common framework enabling pollution reduction of land and sea via sustainable bio-based plastics solutions.

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Success Story: NENU2PHAR - For a sustainable and european value chain of PHA-based materials for high-volume consumer products

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Establishing a European biopolymer value chain from biomass feedstock to finished product

Plastics have become ubiquitous and nearly indispensable, yet they are largely made from fossil fuel-derived compounds and are having increasingly detrimental effects on the environment. One important way to mitigate the negative impacts of the plastics industry while acknowledging its relevance and supporting its existence is to transition away from petroleum-based compounds to bio-derived polymers. Polyhydroxyalkanoates (PHAs) are among the most promising candidates. However, the EU is currently dependent on other countries for much of the PHA value chain. The EU-funded NENU2PHAR project is out to remedy that, taking a holistic approach that includes raw material production with microalgae and bacteria, the formulation and processing of biopolymers and the production of eight different PHA-based products. Plastic is one of the preferred materials for manufacturing high volume consumer products and more particularly packaging thanks to its physical, mechanical, thermal or barrier properties. However, the existing global plastic industry is mainly a petrochemical-based industry, bringing a bad environmental footprint.Polyhydroxyalkanoates (PHAs) are a group of biopolymers that are now widely recognized as attractive substitutes to fossil fuel derived plastics in a wide range of applications. Unfortunately, no sustainable value chain exists in Europe, and production schemes developed elsewhere in the world appear highly questionable from an environmental and ethical standpoint.

The NENU2PHAR project aims at bridging this crucial gap in the EU industry, within an inclusive approach that addresses the whole PHA-based plastic value chain, targeting high volume consumer products. The NENU2PHAR project gathers 17 partners (5 large industrials, 6 SMEs, 5 RTOs and 1 cluster), leaders in the different fields of research, from biomass development to formulation of biopolymer up to plastic processes. First, bio-source will be tackled by developing and optimizing production of PHA biopolymer thanks to the optimisation of carbon feedstock from micro-algae biomass and selection of bacteria strains. Then, innovative polymer processing options will generate different structures with various bulk-surface properties, and various end of life properties. Market uptake of this new PHA will be supported by a competitive cost (5€/kg for PHA compounds), high purity product and processes optimized for PHA bioplastic to tackle functional properties of high volume consumer product better than fossil-based counterparts.

8 PHA-based products will be developed and benchmarked to their fossil-based counterparts. Full validation of the end of life scenarios and environmental footprint will be studied based on biodegradability, compostability or recyclability of the bioplastics formulated.

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Success Story: REPurpose - Rubbery plastics designed for recycling

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REPurpose stands for Recyclable Elastomeric Plastics safely and sUstainably designed and produced via enzymatic Recycling of Post-cOnsumer waSte strEams.

Innovative recyclable elastomeric polymers from post-consumer waste recycling

The application of thermoplastic elastomers in several industrial sectors – from automotive and medical to construction and warehousing – is hindered by recyclability challenges. The EU-funded REPurpose project will upcycle local, post-consumer waste to new functional recyclable elastomeric polymers (REP) targeting the high-value market of thermoplastic elastomers, with applications in the automotive sector, building and construction, and consumer goods. The project will integrate new building blocks derived from biomass or enzymatically degraded plastic and organic waste to deliver REPs with unique features, such as tuneable elastomeric properties without the need for additives, controllable degradation in different habitats, and unprecedented indefinite recycling. In addition, the REPs will be produced, processed and recycled on existing equipment avoiding CAPEX investments.

REPurpose approach

In the REPurpose project, local, post-consumer waste is upcycled to new functional "REP polymers" targeting the high-value market of thermoplastic elastomers that nowadays encounter recycling problems. New building blocks derived from biomass or enzymatically degraded plastic or organic waste will be incorporated giving the REP polymers unique features: i) tuneable elastomeric properties avoiding the need for additives, ii) production, processing and recycling on existing equipment thus avoiding the need for huge CAPEX investments, iii) controllable degradation in different habitats, and iv) unprecedented indefinite recycling, outcompeting fossil carbon with every recycling step. REPurpose's X-factor hence lies in the non-fossil content steering REP to higher value than the original plastic waste fractions: the first biodegradable and recyclable elastomeric polycondensates in the world. The combination of functional strength and the leverage in sustainability in higher-end applications will create considerable market traction when good marketing, production and servicing are surrounding this innovative REPurpose platform.

To enable this development, the REPurpose consortium is spanning the value chain from i) waste handler, recyclers and regulatory framework advocates over ii) specialty bio- or waste-based building block producers, iii) technology developers for REP polymerisation, processing and detection, to iv) end users for consumer goods, automotive and building and construction, all advised by experts in safety- and sustainability-by-design, life cycle assessment, business modelling and Responsible Research and Innovation. Four universities and research centres, a non-profit organisation, six SMEs (including two start-ups) from seven EU countries and the

UK address the research challenges and pave the way for bringing the innovation to the broad public and creating a resilient and sustainable European plastics industry.

Acknowledgments: REPurpose project is funded by the European Union, Horizon Europe Funding Programme for research and innovation under grant agreement Nr. 101057971

Cordis: https://cordis.europa.eu/project/id/101057971
LinkedIn: https://www.linkedin.com/company/repurpose-safe-and-sustainable-by-design-rubbery-plastics/

Presentation in open access: https://zenodo.org/record/7941980
Recording on YouTube: https://youtu.be/Ewc6-VOD4FM

Success story: GLAUKOS- Circular Solutions for the textile industry

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Glaukos is the Greek sea god of fishermen. He was commonly believed to protect the oceans, as is the ambition of this project by developing innovative alternatives for textiles that are currently polluting our oceans.

Glaukos project will develop biobased textile fibres and textile coatings that are adapted to the needs of the 21st century. The complete life cycle of clothing and fishing gear will be redesigned, their sustainability performance will be enhanced significantly, while their technical performance will be matched to end-user requirements. The ambition is to significantly reduce the carbon and plastic footprint of clothing and fishing gear.

The objectives of the project are

- Develop eco-friendly fishing gear coatings with increased biobased content and increase the biobased content of textile products
- Mitigate microplastic pollution by increasing the biodegradation rate of materials compared to conventional plastics
- Reconcile the biodegradation characteristics with technical performance and durability to ensure the effective and long-term use of textile products such as fishing gear and clothing
- Boost the bio-recycling potential of Glaukos biobased textile products by developing compatible recycling biocatalyst
- Engage stakeholders across the textile industry and communicate with the broader public
- Enhance the framework for sustainable innovation in the textile industry by developing new tools for Life Cycle Assessment of the textile value chain

Glaukos systematic approach

The consortium partners of the Glaukos project are among the leading experts in the various sectors of the entire value chain for the development of eco-designed fishing gear and clothing, and for the scaling up of the production process, all the way from renewable feedstock to textile prototype and ending with end-of-life solutions: biodegradation and bio-recycling.

Acknowledgments: Glaukos project has received funding from the Bio-based Industries Joint Undertaking (JU) under the European Union's Horizon 2020 research and innovation programme under grant agreement No 887711. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio-based Industries Consortium.

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Presentation in open access: https://zenodo.org/record/7941980
Recording on YouTube: https://youtu.be/Ewc6-VOD4FM

Success Story: ECOFUNCO - Eco sustainable multi Functional biobased Coatings with enhanced performance and end of life options

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Keywords: coating, biomass, chitin, cutin, protein, packaging, health care

Introduction

The ECOFUNCO project was inserted in the European Strategy for Bioeconomy, and followed a circular economy approach by addressing valorisation of biomass derived from by-products and waste of agri-food sector, targeting exploitation in food packaging, increasing food security, and in the cosmetic field. The reduced dependence from petro-sources will make Europe less dependent on gas and fuel imports, and the use of bio-based materials will contribute to balance the carbon dioxide emissions.

The present contributes reports and overview of project results and validation of the demonstrators achieved (Figure 1).

Figure 1: Scheme of the ECOFUNCO project

Experimental

ECOFUNCO has addressed firstly the extraction of proteins, polysaccharides, cutin, polyphenols, lipids and the production of biopolymers (polyhydroxyalkanoates, microbial cellulose) from residues derived from shrimps, mushrooms, tomato, legumes, watermelon, apple, sunflower, etc. The extraction was performed by using conventional chemical methods but also by using innovative alternative sustainable technologies, such as microwave and ultrasound assisted extraction and supercritical Fluid Extraction (MAE, UAE, SFE), and the use of green solvents. This approach resulted extremely positive and advantageous and two patents were applied related to innovative extraction technologies.

The biomass derived molecules addressed in the project, such as proteins for oxygen barrier, chitosan-chitin for antimicrobial activity, polyphenols for antioxidant activity, and cutin for barrier to water vapor, were then used for the development of wet and hot melt polymers-based coatings applied on cellulose and plastic substrates provided by ECOFUNCO partners.

Results and Discussion

Positive results in coating on both cellulose and plastic substrates were achieved by wet coating, hot melt coating and electrospinning technologies differentiate for coating composition and applications. The coated substrates confirmed the performance of protein and chitosan for barrier to gas, cutin for barrier to moisture and chitin and polyphenols for antimicrobial and antioxidant activity.

The best performing formulations were scaled up, produced in the amounts of kilos (liters), and applied by industrial partners on cellulose and on plastic substrates, while the coating process was inline monitored. The coated plastic and cellulose sheets were assembled to produce multi-layers packaging for perishable food, validated on cheese and ham, while non-woven tissue, and cardboard boxes were validated for improved antioxidant/antimicrobial activity, skin contact compatibility, etc.

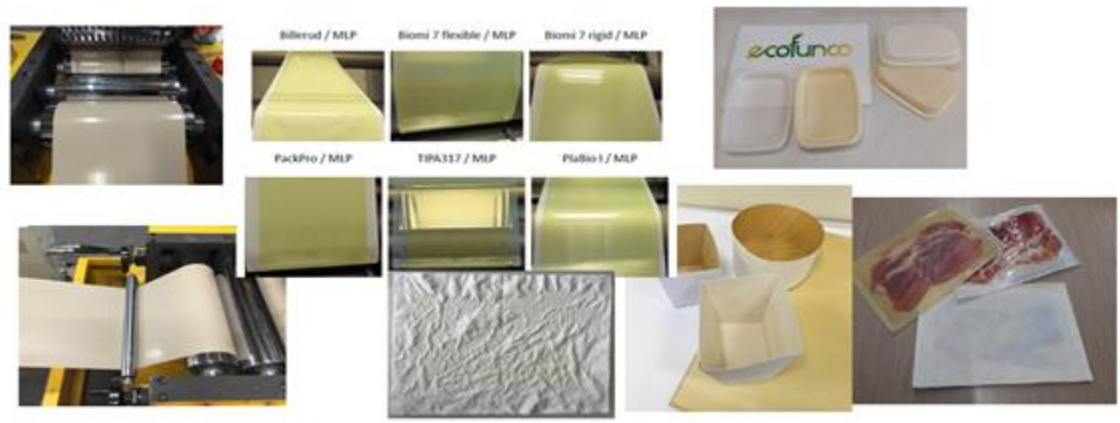

*Figure 2: ECOFUNCO product*s

The compostability, biodegradability, life cycle cost and life cycle assessment were also assessed and included in the validation and exploitation strategy for ECOFUNCO products.

Conclusions

ECOFUNCO materials have been developed on pilot and industrial scale and validated for food packaging and for health care. The overall cost, social environmental impact of the entire

value chains addressed in the project was evaluated, some of the materials produced resulted very promising for an industrial exploitation.

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Presentation in open access: https://zenodo.org/record/7937832
Recording on YouTube: https://youtu.be/t295i8Kh6Ek

Success Story: RECOVER - Development of innovative biotic symbiosis for plastic biodegradation and synthesis to solve their end of life challenges in the agriculture and food industries

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Keywords: Agri-food waste plastics; microplastics; microorganisms; enzymes; insects; earthworms; biodegradation modeling; chitin-based biopolymer; eBeam; compost; biofertilizer; mulching film

A new biotechnological approach for plastic biodegradation is possible. The present work in RECOVER presents a concrete example from an ongoing research and innovation action, aiming to increase the actual plastics recycling share.

About 70% of the plastic waste collected in the EU is incinerated, landfilled, or exported to other countries. To encourage its reuse, the EU has adopted a recycling target of 55% by 2030 for household plastic packaging waste, complemented by voluntary commitments from the European plastics industry to recycle 70% (plastic packaging) and 50% (all plastic waste) by 2040. However, there is a lack of knowledge about possible tangible solutions to achieve these ambitions. The challenge is to increase recycling rates and change the unfavorable structure of plastic waste reuse. Currently, the energy recovery rate (41.6%) is even higher than the recycling rate (31.1%), and the recycling rate only slightly exceeds that of the landfill rate (27.3%) [1].

Poor segregation of waste at source, multilayers in plastic items and inefficient collection of recyclable materials are among the barriers for achieving a higher recycling rate. To address this, the RECOVER project, financed by the BBI JU H2020, proposes new recycling routes for non-recyclable mixed plastics using a combination of insects, microorganisms, earthworms and enzymes to convert plastics into biofertilizers and bio-based materials for food packaging and agricultural applications.

Within this framework, RECOVER shows preliminary results on

- characterization of non-recyclable plastic fraction in municipal waste streams and testing of tools for plastics sorting and monitoring in these waste streams;
- physical and chemical treatment of plastics that could facilitate further biological treatment; and

- treatment of plastics with insects.

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Success Story: PRESERVE - PHA coating for fibre based packaging

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In Europe, almost 50 million tonnes of mainly fossil-based plastics are consumed per year, of which only 32% is currently recycled. The largest part is still being incinerated or landfilled, contributing to the depletion of the limited resources. The largest market of plastics (more than 40%) are packaging applications. Furthermore, only 1-2% of these plastics are biobased or biodegradable, although these have advantages in terms of switching to renewable feedstocks and end-of-life modularity.

Within the PRESERVE project 10 different packaging demonstrators will be developed using biobased and/or biodegradable polymers, resulting in alternative materials and processes for more than 60% of the plastic packaging that are currently on the market.
Some of these demonstrators involve the use of paper-based packaging, which is becoming increasingly popular due to the opposition of many consumers against plastics. However, many consumers don't know that paper packaging quite often also contains plastics and synthetic chemistries. Mostly these are made to be compatible with the recycling process.

Acrylates are for example used to "glue" the paper pulp together in a strong paper, but readily dissolve when added to water, which allows for an easy recycling process. However, in the case of barrier coatings, polyethylene coated paper is often used. This ultra-thin polyethylene coating gives superior properties to the packaging, but this complicates the recycling.

This presentation will focus on Centexbel's development on barrier coatings for paper substrates using polyhydroxyalkanoates (PHA). The coatings are developed to have both a good barrier against moisture, water and/or fat, while at the same time being recyclable and biodegradable.

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Recording on YouTube: https://youtu.be/Ewc6-VOD4FM

Lessons learnt: Compostable and biodegradable materials part of a sustainable world - innovative examples of EU research

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Plastic contamination of the environment has become a serious problem. Prevention of waste and re-use are the first strategies for decreasing the plastic waste, but this is not possible for all applications. Therefore, end-of-life strategies must be well elaborated to give an answer to this problem.

While conventional materials can be recycled mechanically or chemically, compostable products can additionally be effective and eco-friendly treated by industrial composting. This offers unique opportunities for food packaging, often consisting of a range of different materials and contaminated with food residues, as recognized by the proposed EU regulation on packaging and packaging waste. When these compostable materials are produced of renewable resources, one can truly speak of a circular economy.

This presentation will explain the different requirements on industrial compostability as defined by EN 13432 and show the opportunities and challenges. Moreover, the need for biodegradability (complete mineralisation) of applications that are applied in the open environment such as on land or sea will be demonstrated. As biodegradation is dependent on the environment, attention must be given to correct test procedures.

This all will be demonstrated by different innovative product examples of current EU-funded research projects.

Presentation in open access: https://zenodo.org/record/7936528
Recording on YouTube: https://youtu.be/Ewc6-VOD4FM

Lessons learnt: Sustainability and End of Life studies of new packaging. Lessons learnt from the BBI-JU - MANDALA Project

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Keywords: LCA (Life Cycle Assessment), sustainability, circular economy, biodegradability, compostability, disintegration, end of life validation

Introduction

Food packaging facilitates storage, handling, transport and preservation of food and it is essential for preventing or at least decreasing food waste. Besides these beneficial properties, food packaging causes rising concern for the environment due to its high production volume, often short usage time, and problems related to waste management and littering. Reduction, reuse, and recycling, but also redesign support the aims of the Circular Economy to decrease the environmental impact of food packaging: the sustainability of packaging made from natural and synthetic polymeric materials developed within the MANDALA project is provided and discussed.

In particular, the End-of-life of compostable packaging sent to controlled composting plants can be an important method of reducing garbage. The main prerequisites defined by official regulations are related to biodegradability, physical breakdown and the quality of the compost produced in terms of agronomic parameters and toxicity towards plants, and these requisites for the compostability assessment are defined in the EN 13432 official Standard[1]: the biodegradability of the test material is determined in a laboratory aerobic controlled composting test based on the evolution of carbon dioxide. The laboratory tests are followed by investigations of the disintegration of the material in composting reactors and analysis to determine the quality of the final compost produced.

The new packaging developed during MANDALA project were tested accordingly and the results are provided: this study demonstrates the compostability behavior of these products.

Experimental

Life Cycle Assessment (LCA) was performed according to the ISO 14040-44 standard[2,3], following the sequence steps: (i) goal and scope definition, (ii) inventory analysis (LCI), (iii) impact assessment (LCIA) and (iv) results interpretation. The commercial software SimaPro 9.2 and available databases were used in order to carry on the analysis.

For impact assessment the EF 3.0 method[4] was chosen thanks to its comprehensive vision on environmental problems associated with a product life cycle, and the included weighting phase and single score aggregation procedures (optional step in the LCIA phase).
Biodegradation test was performed as described by EN ISO 14855-1 standard[5]: three composting vessels were used for each type of testing sample. 600 g of compost was used for biodegrading 60 g of the testing sample. Three positive controls and three blank composting vessels are used as described in the standard. The measurement of the produced CO_2 is carried out daily.
The disintegration test is performed according to ISO 16929 standard[6]: two composting vessels were used for each type of testing sample. 15 kg of compost was used for disintegrating 150 g of the testing sample. Two blank composting vessels are used as described in the standard. The disintegration is quantified by gravimetric test.
The final compost quality is evaluated according to OECD 208[7]: starting from a stabilization process under thermophilic conditions and elapsed for 12 weeks applied on 15 kg of compost and 1,5 kg of milled tested material: the final composted sample is analyzed in terms of agronomic parameters and ecotoxicity toward two different plants (*Hordeum vulgare* and *Lepidium sativum*).
All the biodegradability tests under different conditions are performed according to standard: home biodegradability test following EN ISO 14855-1 standard[5] (at temperature below 30°C), soil biodegradability test following ASTM D5988:2018[8], marine biodegradability test following ASTM D6691:2017[9], freshwater biodegradability test following ISO 14852:2021[10].

Results and Discussion

For the purpose of the MANDALA project, the LCA study considers the environmental burdens associated with the production of 1 m^2 of packaging film in a “Cradle-to-grave” approach: the selected bioplastic materials compared with the fossil-based one (as benchmark) represent the largest share of the total impact of "cradle" and "grave" stages for both products (almost 30%). Furthermore, MANDALA raw materials are characterized by higher impact for their production, but lower impacts for their end-of-life options if compared to benchmark fossil-based raw materials.
About the end-of-life study, the tested packaging is analyzed according to EN 13432 standard: i) the biodegradation tests on the selected samples provide the compliance with the EN 13432 requirement defined as more than 90% of biodegradability percentage reached within 6 months under industrial composting condition. ii) the disintegration requirement (sample reduced into dimension less than 2 mm) is fulfilled reaching more than 90% within 12 weeks. iii) the final compost quality analyzed both in terms of agronomic parameters and ecotoxicity towards two different plants is assessed: the tested packages are in compliance with the limits defined from the European Fertilizers Regulation and provide a germination rate and biomass growth more than 90% compared to the control sample (to indicate the not toxic effect for the plant growth by using the final compost as fertilizer).
Furthermore, the final composition of the developed packaging is tested for biodegradability determination under several environments: home composting, soil (still ongoing), marine and freshwater: all the completed biodegradability tests provide more than 90% as percentage of transformation of the organic carbon into CO_2, within the specific timeframe of the test. The soil biodegradability is 77% after less than 1 year with a continuous production of CO2, meaning that the test is not finished, yet.

Conclusions

The new packaging products developed during the MANDALA project are tested for the assessment of the biodegradability and compostability performances and are studied for LCA: the obtained results provided the compliance with the current EN 13432 Regulation and the quantification of the main environmental impacts and sustainability of the materials and the proposed technologies.

Acknowledgments: These projects have received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 837715. The authors want to thank the partners for the collaboration and sharing the information on processes and products.

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Presentation in open access: https://zenodo.org/record/7936546
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europeanbioplastics

Conclusions of the conference: 12 European projects leading by example

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Today 12 EU-funded projects have demonstrated that there are feasible and viable solutions for a transition to non-fossil bio-based plastics. All these projects, from different perspectives, have implemented solutions to tackle the plastic pollution problem at its roots, and to reduce our impact on the environment. These 12 projects are outstanding examples of European innovation in terms of implementation of novel materials, products, and processes.

Ecodesign for packaging products is not only technologically feasible, but also economically viable. The four twin projects BIOnTop, Usable Packaging, CelluWiz, and MANDALA have designed new processing systems for functional bio-based packaging products that are **reusable, recyclable, and/or compostable and bio-degradable, as an alternative to the currently identified benchmark products.** Within their lifetime, the projects have proven that the packaging products are recyclable or compostable/ bio-degradable in various environments and able 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. These solutions and products were developed with consumer organizations, recyclers, and composting plant representatives.

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*.[4] Bio-based plastics are made from renewable sources, such as organic waste, lignocellulosic, and agro-based feedstocks.

During today's conference, we have learned **how bio-based, bio-degradable and compostable plastics can contribute to ending plastics pollution** by:

- Reducing the plastics' negative climate impacts by replacing virgin fossil feedstocks with non-fossil bio-based feedstocks. Plastics production is currently 90% based on virgin fossil raw materials[5]
- Reducing single-use plastics coupled with the substitution of non-recyclable plastics for certified compostable material can help reducing overall GHG emissions and environmental impact.

[4] SYSTEMIQ (2022). ReShaping Plastics: Pathways to a Circular, Climate Neutral Plastics System in Europe. https://www.systemiq.earth/raw-materials-europe/
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Today, we also discussed biodegradation, compostability and home compostability: Biodegradation is a natural biochemical process during which microorganisms present in the environment convert bio-degradable materials into carbon dioxide, water, and biomass. While conventional plastics do not decompose at the end of their life, plastics referred to as 'bio-degradable' are designed to decompose at the end of their life by the conversion of all their organic constituents (polymers and organic additives)[6].

Industrial compostable plastics are a subset of bio-degradable plastics designed to biodegrade in well-controlled industrial composting facilities without negative effects on the compost, i.e., the outcome of organic recycling. They are especially suitable for food packaging applications as they allow a higher biowaste capture and will result into lower contamination of compost by non-biodegradable plastics.

The transition to non-fossil bio-based plastics is key to addressing conventional plastics' growing climate impacts at the global level and foster a sustainable circular economy.

There are several initiatives underway in this area **in Europe.**
To name but a few, the "Microplastics Initiative" and the "Substantiating claims on the environmental performance of products and businesses Initiative". Parallelly the European Commission has proposed several regulations that have the same final goal: the Packaging and Packaging Waste Regulation proposal (currently undergoing heated discussion between all stakeholders and legislators), or the Eco-design for Sustainable Products Regulation. Plastic pollution, our environmental impact, and climate change are addressed in all these initiatives and proposals. The European Union also contributes to this goal through Horizon Europe and the financing of research and innovation projects developing innovative solutions and products.

Meanwhile, at an **international level**, there is an emerging internationally binding initiative that requires the attention of those working in applied research.
We are referring to the UN Global Plastics Pollution Treaty, which is currently being discussed at intergovernmental level. The Treaty is an Initiative of UNEP/UN to fight internationally plastic pollution. It is a treaty to be adopted by 2024 in 175 countries, a legal binding international agreement for governments to fight plastic pollution. The Treaty catalyzes the transition to non-fossil biobased plastics and leverages innovative bio-degradable and compostable plastics to help end plastic pollution by 2040 all while ensuring the alignment to the Paris Agreement.

The outstanding 12 projects that participated at this conference have shown today that Europe can lead by example at an international level. Today the speakers have brought into the discussion a wealth of excellent examples of how novel sustainable bio-based solutions:

6 Commission's Group of Chief Scientific Advisors, Biodegradability of plastics in the open environment, European Commission www.europa.eu. European Commission, EU Policy Framework on bio-based, bio-degradable and compostable plastics COM(2022)682.

- Can be based on sustainable materials.
- Can demonstrate efficient use of raw materials.
- Can make it possible to shift from virgin fossil materials to sustainable materials.
- Can help meet societal demands for products with a low impact on the environment.
- Can reduce environmental pollution and GHG emissions and indirectly help the fight against climate change.

These projects show above all that their findings and results contribute to sustainable solutions for us all.

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