



Granting society with LOw environmental impact innovative PACKaging

Key results booklet

November 2021







PREAMBLE

BY THE GLOPACK PROJECT'S COORDINATOR:

I am glad to present you this key results booklet on behalf of the entire GLOPACK team. Since the kick-off meeting in June 2018, and despite the challenging times we have gone through due to the Covid 19 pandemic, we worked tirelessly to set up a cross-value chain dialogue, bringing together different disciplines, value chains, academics and industrials, to move into a positive spiral of the co-creation process. I must say that we met the challenge and now we can be very proud of our projects' achievements!

Our solutions will contribute to solve the environmental issues of the food packaging sector and will be a game-changer towards a positive perception of packaging used for food preservation, decreasing food waste and loss and mitigate the negative burden of packaging resources and post-usage fate, especially plastic accumulation.

We look forward to seeing our solutions and innovations progress even further, coming to the market and contributing to an improved and more sustainable society.

Valérie Guillard,
Professor, University of Montpellier, France
September 2021

Introduction

Around 100 million tons of foods are wasted annually in the European Union, nearly 30% of the agri-food supply chain, which leads to huge environmental impacts (high carbon footprint and blue water footprint, vain land use, etc.). Food waste is expected to rise to over 200 million tons by 2050 while an increase of 50% in food supplies will be needed globally.

In the meantime, more than 23 million tons of plastics are consumed for plastic packaging in Europe each year (2020 data) - 40 % of this plastic packaging is for food. Among these 23 million tons of plastics, only 18 are collected, 7.7 million tons are recycled - only 1.2 million tons for close loop recycling, i.e. to produce new packaging items. 10 million tons are either lost or landfilled contributing to a yearly increase in the problem of plastic pollution.¹

Packaging is an essential element of response to address the key challenge of sustainable food consumption on the international scene. Minimizing the environmental footprint of the packed food is clearly about reducing food waste and loss while eradicating plastic pollution and the risk of micro and nano-plastics.

In this context, the GLOPACK project aimed to lift the barriers to market uptake of sustainable packaging solutions by providing a favourable technological, social and economic framework within a 3.5-year time frame. To address the dual challenge of minimizing food waste and loss while fighting plastic pollution, the project is focusing on solutions that are 100% biodegradable in natural environment and bringing new functionalities to enhance the packaging usage benefit (active functionalities to increase shelf life and freshness tracking).

Key project information

Funding Programme	H2020-EU.3.2.2.3. - A sustainable and competitive agri-food industry
Topic	SFS-35-2017 - Innovative solutions for sustainable food packaging
Type of action	Innovation action
Duration	June 2018-November 2021
Consortium	16 partners from 7 countries
Coordinator	UNIVERSITE DE MONTPELLIER from France



The objectives of GLOPACK

GLOPACK proposed a cutting-edge strategy addressing the technical and societal barriers to spread in our social system, innovative eco-efficient packaging able to reduce food environmental footprint.

The project focused on increasing the Technological Readiness Level (TRL) of three main promising advances in the food packaging area:

1. "bio-circular" (biodegradable materials issued from agro-food residues conversion) biopolymer,
2. thermoformed and injection moulded "bio-circular" food packaging
3. active packaging to improve food preservation and shelf-life resulting in reduced levels of additives and
4. RFID enabled biodegradable sensor, wireless food spoilage indicator as a new generation of food quality tracker self-adjusting food date label,
5. a decision-supporting tool to provide unique and specific guidance to food and packaging SMEs in terms of the selection of the most sustainable packaging alternatives. The tool proposes, among others, a fair and transparent appraisal system of the sustainability of the food/ packaging as a whole through the GLOPACK packaging score.

To support the market uptake of these innovations, the GLOPACK consortium developed the following knowledge transfer tools:

- the GLOPACK Best practice Guidelines for Biodegradable packaging;
- the GLOPACK Recommendations and guidelines for the development of FOP label.

A multistakeholder platform was set up and operated to support the work plan of the project.

This booklet aims at summarising these key achievements of GLOPACK project achieved between June 2018 and November 2021.

The list of innovations and results

The GLOPACK “bio-circular” biopolymer

The GLOPACK food packaging material is based on poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), which belongs to the family of polyhydroxyalkanoates (PHAs). An hydroxyvalerate (HV) content of about 20% is targeted to improve the processability as packaging material of the PHBV produced.

PHAs is a family of bacterial polyesters that are

- fully bio-based and fully biodegradable in natural conditions, e.g. home compostable.
- able to substitute currently used fossil-based food packaging materials.

The PHBVs developed in the GLOPACK project are produced by mixed bacterial cultures from fermentable organic residues (corn cob or fruit juice residues) at two pilot plants:

- Isola Della Scala, Verona, Italy owned by Innoven,
- Biopilot Plant in Portugal owned by iBET.

Technology readiness level of the innovation	
At the start of GLOPACK	At the end of GLOPACK
TRL4	TRL7
Technology validated in lab	System prototype demonstration in an operational environment

KEY ACHIEVEMENTS:

- **The production of naturally biodegradable PHBV polymer on a larger scale is feasible.**
A total of ~ **66 kg of raw polymer** were produced in the framework of the project (~ 40 kg after extraction/purification). PHBV can be produced from fermented fruit waste (HV of ~18%) with a production yield of about 200 kg of PHBV per ton of dry matter.
- **For a PHA-tray production economically viable.** 50-60 tons of biopolymer per year² (~ 40-50 t after extraction) is feasible to produce in one plant with reactor units of about 44 m³ (for acidogenesis and production) to 73 m³ (for the culture selection).
- The use of an optimized eco-efficient mixed microbial cultures-based process permits to decrease investments and operating costs of PHBV conversion with respect to pure culture and makes easier the use of no-costly by-products as feedstock (corn cob or fruit juice residues).
- **Tuning of HV content is feasible;** a quite well stable ~18% HV content was repeated from batch to batch despite biological variability. Increase HV content permits to decrease

the melting point of the material and enlarges the processing possibilities (blending, etc.).

- **Extraction and purification steps lead to some losses (up to 25%).**
- **Polymer purification is a key step** of the process and determines the further processability of the material as food packaging material. An increase of HV content alone is not enough to improve the flexibility of the final material and enlarge the window of processability by the classical thermomechanical process.



The GLOPACK “bio-circular” food packaging

Two different packaging processes were tested within GLOPACK: thermoforming and injection-molding. Both were used to produce semi-rigid containers which were further tested in operational conditions by food companies on different food case studies (dairy product, fresh meat, ready-to-eat veggie food).

Technology readiness level of the innovation	
At the start of GLOPACK	At the end of GLOPACK
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Technology validated in lab	System prototype demonstration in an operational environment

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- **Lab-scale thermoforming and industrial-scale injection moulding of PHBV material (use of commercial-grade) to produce containers is feasible.** 300 running meters were extruded with commercial PHBV material for further thermoforming, ~ 150 thermoformed trays were produced, a total of ~ 3000 items (trays and cups) were injected within the project. PHBV materials are more easily processable using injection moulding than thermo-forming.
- **The incorporation of 20% of fillers such as purified cellulose fibres in injection-moulded cups is feasible.** It would lead to a cost decrease of the raw material from 5€/kg (for pure PHA) to 4.2 €/kg for the compound with 20% of fibres while maintaining its processability, biodegradability kinetic and food contact suitability³. The incorporation of 40% of fillers would lead to a cost decrease until 3.4€/kg.
- **The O₂ and water vapour barrier properties of the PHBV GLOPACK packaging** were found lower than those of the benchmark and compatible with the targeted applications (modified atmosphere packaging).
- **Food regulatory assessment.** The food regulatory status of the valerate-rich PHBV biopolymers produced by new microbial strains and new feedstock materials was evaluated and the necessity as well as the process of the authorisation procedure at EFSA prior their commercial use was clarified. Several final packaging articles were analytically characterized by migration and screening tests, which gave insights on possibilities and limitations for potential packaging applications with respect to regulatory and safety aspects.
- **Shelf life tests confirmed the ability of PHBV containers (with commercial lid films) to pack food items with a shelf life as good as for the benchmark.**

³ Calculation made for a tray of about 500 mL of volume and 30 g considering that filler cost is about 1€/kg and that the bulk biopolymer is about 5€/kg

The GLOPACK active antimicrobial PHBV packaging.

Antimicrobial compounds were incorporated into the biodegradable GLOPACK PHBV packaging to improve food preservation and the shelf-life of products.

- The antimicrobials are based on carvacrol and oregano essential oil (volatile antimicrobial emitters) and ethyl lauroyl arginate (LAE) (a non-volatile compound that is acting by contact or after diffusion into the food) to prevent microbial spoilage.

	Carvacrol or oregano essential oil in the PHBV matrix	LAE (Ethyl lauroyl arginate, E-243) in the PHBV matrix
Process applied	thermoforming process	injection molding
Food application tested	falafel (vegetarian foods) and fresh cheese in MAP packaging	fresh cheese in MAP packaging

Technology readiness level of the innovation	
At the start of GLOPACK	At the end of GLOPACK
TRL3	TRL6
Experimental proof of concept	Technology demonstrated in relevant environment

KEY ACHIEVEMENTS:

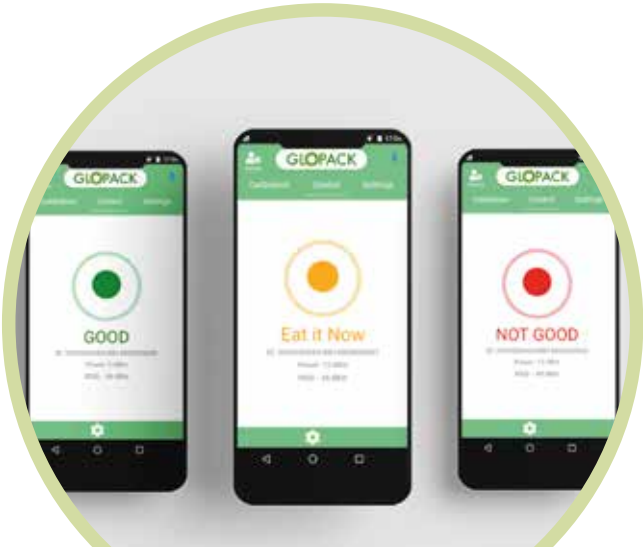
- **Requirement driven approach** to design active packaging materials (PHA-based materials containing anti-microbial compounds) was tested with small quantities of material: it considers at the early stage of the material scaling up, all the food, consumer, market and legal requirements that the material should comply with.
- **Dedicated mathematical algorithms** that predict the complex diffusion-reaction system and release kinetic into the headspace of volatile and non-volatile antimicrobials; permit to tailor active biodegradable material in such a way that it complies with the consumer daily intake limitations, including its natural occurrence in food products and taking also into account the product needs in terms of food quality and safety and shelf-life extension.
- **~ 280** cups of commercial PHBV containing LAE were injected and used for further testing.



The GLOPACK low-cost, battery-free RFID tag system to track red meat freshness

The GLOPACK sensor-enabled RFID system was developed to monitor the freshness of food during transportation and storage. The bio-layer sensor applied made the system more intelligent, adding sensing functionality to the classical RFID tag: it provides information about the food quality status through detection of internal gas composition changes in the headspace.

The RFID system is supported with an Android IOS compatible mobile application to visualise the signal and helps the user to decide whether the product is still consumable or not.



Technology readiness level of the innovation	
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TRL3	TRL6
Experimental proof of concept	Technology demonstrated in relevant environment

KEY ACHIEVEMENTS:

- 2 rolls of 5000 pcs of RFID tag were industrially processed. About **300 pcs of RFID tags** were coated with the biosensing layer. A smartphone application was developed to easily track food freshness through NFC reading.
- **Low-cost RFID bio-based sensor** adapted to detect food freshness based on the coupling of a passive RFID tag obtained with printed electronics on paper or plastic labels (allowing a process costs decrease; with **an expected cost lower than 0.10 € per tag**) with a protein-based layer: the biosensing layer induces changes in the RFID response when detecting a threshold content of targeted molecules (CO2 and other organic volatiles) in the packaging headspace. The sensor was successfully validated in an operational environment on red meat packaged in modified atmosphere packaging (MAP).
 - **An integrated system**, when coupling the RFID data to the developing technology of the “Internet of Things” (IoT). The system can cover the entire food supply chain allowing optimizing inventory, quality & shelf-life tracking by providing real-time information.



The GLOPACK Decision Support System (DSS) for packaging decisions

The Decision Support System (DSS) is a tool designed to allow food manufacturers/packaging producers to get insights into the packaging materials available for their specific use case and to help them to select the material which best matches their needs.

The tool encompasses a comprehensive database of packaging materials and their key performance characteristics such as O₂ and CO₂ permeabilities, consumer preferences (transparency, compostability, biodegradability, recyclability), the GLOPACK eco-score along with additional qualitative data such as consumer surveys to allow for ranking of packaging materials based on those most likely to be accepted by an average consumer.. The GLOPACK score computed, using additional user answers to a list of questions, allows a fair and transparent evaluation of the sustainability of the food packaging and can be a tool to communicate to all customers and consumers about eco-efficient packaging alternatives.

The GLOPACK Decision Support System is available here: glopack.expertmodels.com

Technology readiness level of the innovation	
At the start of GLOPACK	At the end of GLOPACK
TRL4	TRL7
Technology validated in lab	System prototype demonstration in an operational environment

KEY ACHIEVEMENTS:

- **Four stand-alone applications** permitting to design passive (MapOpt tool) or active MAP system (usable at this moment for few active components such as iron-based O₂ scavengers or volatile anti-microbial), to determine the concentrations of migrant substances (from packaging materials) in food (Facet tool).
- **One early guidance software and associated databases** to help users to select sustainable material options, based on multicriteria database query. The tool helps to reach a compromise and to provide an answer to the sometimes contradictory concerns of environmental, economic and social interests of innovative sustainable packaging technologies.
- A database containing **331** packaging solutions & **2205** packaging characteristics are now available.
- **The GLOPACK score calculation tool** is a transparent evaluation system of the sustainability of food together with the packaging.

The GLOPACK Eco-Score

The GLOPACK score is an environmental score of 5 points that permits to easily compare the environmental impact of food packaging.

The GLOPACK score encourages the consumer to choose a packaging that

- has less impact on resources and uses environmental-friendly manufacturing methods
- brings optimal functionality, i.e. protects the foodstuff as required without overpacking
- has environmental-friendly waste treatment options

The GLOPACK score is a score from 1/5 to 5/5, which synthesizes the individual score of three main pillars for packaging concepts: **Materials, Functionality and After use.**

KEY ACHIEVEMENTS:

- **Informative, easily understood, science-based front-of-pack (FOP) sustainable labelling** that permits to promote the GLOPACK packaging benefits in terms of materials, functionality and after use compared to current packaging material benchmarks.

The GLOPACK Best practice Guidelines for Biodegradable packaging

The GLOPACK Best Practice Guidelines for Biodegradable Packaging for Food are a comprehensive and practical document on the main aspects of the development and usage of biodegradable, active and intelligent food packaging.

These Guidelines are unique as they summarize and present the lessons learnt from the GLOPACK project and results from the strong cooperation between the project partners.

The Guidelines can be downloaded from the GLOPACK website.

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The GLOPACK Recommendations and guidelines for the development of FOP label

These recommendations were developed based on the experiences of the GLOPACK project.

The Guidelines can be downloaded from the GLOPACK website.

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The GLOPACK Stakeholders' Platform

The multi-stakeholder platform, set up by the GLOPACK Consortium, intended to provide a forum for knowledge and information exchange and to stimulate discussions related to food packaging and valorisation issues, based on the needs and expectations of the experts and potential users in the future.

The GLOPACK Stakeholders' Platform consists of 32 members from 8 countries and includes

- 16 Companies (packaging producers, food producers, retailers)
- 9 Innovation Hubs and Clusters
- 4 Research Institutions
- 2 Consultancies
- 1 Civil organization

During the GLOPACK project, Stakeholder Events and webinars were organised to keep our members up to date on the progress of the project.

Conclusion

Launched in 2018, GLOPACK has sought to lift the specific barriers and major identified challenges to scale up and commercialize the three most promising technologies in the sustainable food packaging area: bio-circular, active and intelligent packaging. Over the project's three and a half years, GLOPACK has met to provide these key unlocking technologies the necessary user-driven strategy and tools to enter the positive spiral of demonstrated technical, social and environmental benefits.

GLOPACK has generated new knowledge, created new tools and solutions to fight against plastic pollution and food waste and allow shifting from a linear to a circular economy.

The multi-stakeholder GLOPACK consortium comprised of 16 partners from 7 countries, representing academics, applied research centres, professional associations and SMEs who worked tirelessly together to endow the food and packaging industry with a range of finalized PHA-based materials including tailored active and intelligent (RFID bio-sensor) functionalities. To enhance the stakeholders' ability to make informed choices on adopting sustainable packaging innovations, a decision support tool was developed allowing to identify the optimal material that takes all food, market and citizens' requirements into account.

To ensure that all the results are used by the key stakeholders of the sector, GLOPACK has carried out customized dissemination and transfer activities. Communication and dissemination of the benefits of GLOPACK solutions will (re)gain the consumer's and market's trust in bio-, active and intelligent packaging solutions. Through its Stakeholders' Platform, GLOPACK bridges the gap between the food packaging chain diverse players (R&D, food and packaging industry and consumers) to quickly track the use and acceptability of innovative bio-, active and intelligent food packaging solutions. Stakeholder's workshops and dedicated events contribute to bringing GLOPACK results directly to the industry and it is hoped that this effort will translate into new collaboration opportunities and follow up actions.

The GLOPACK team is confident that the project's results implementation will lead to increase the sustainability of the food area as a whole, by supporting the growth of more circular food packaging options that are safe for the environment, by preserving food quality and safety and decreasing the corresponding negative impact of food losses and waste on our environment and economy.

ACKNOWLEDGEMENTS

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GLOPACK

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