Novel technology to boost the European Bioeconomy: reducing the production costs of PHA biopolymer and expanding its applications as 100% compostable food packaging bioplastic

Rendicontazione

Informazioni relative al progetto

EUROPHA

ID dell'accordo di sovvenzione: 604770

Progetto chiuso

Data di avvio
1 Ottobre 2013

Data di completamento
30 Settembre 2016

Finanziato da
Specific Programme "Capacities": Research for the benefit of SMEs

Costo totale
€ 2 093 640,80

Contributo UE
€ 1 572 902,10

Coordinato da
FEDERACION DE COOPERATIVAS AGRARIASDE MURCIA S COOP
Spain

Questo progetto è apparso in...

23 Ottobre 2017

Final Report Summary - EUROPHA (Novel technology to boost the European Bioeconomy: reducing the production costs of PHA biopolymer and expanding its applications as 100% compostable food packaging bioplastic)

Executive Summary:
Bioplastics like polyhydroxyalkanoates (PHA) are long-term sustainable alternatives because they can show equal performance to conventional petrochemical plastics, originated from renewable non-food resources and are 100% bio-degradable. However, one of the main obstacles for the market uptake of PHA is a higher price compared to other bioplastic (starch- based or PLA).

EUROPHA R&D Project has been devised to take advantage of the waste generated by the agri-food industries to produce 100% bio-degradable polymers, in particular poly (hydroxyalcanoates) (PHA), which could be employed in the manufacture of films and foamed articles as substitutes for materials derived from petroleum that are currently used in the packaging industry.

EUROPHA project seeks to PHA bioproduction process able to reduce the production cost of the final plastic at industrial scale by covering the whole production cycle of the PHA. Packaging industries can re-use their surplus streams as low-valued feedstock as starting material in the synthesis of an added-value product, saving at the same time waste treatment costs. This also will increase the since the small market share of European PHA (dominated by China and US) that limits the potential of a European bioeconomy.

EUROPHA strategy for production of PHA uses mixed microbial cultures, from sugar-enriched waste coming from agri-food industry, instead of conventional food-stuff used currently. The process consisted of four stages: acid fermentation, selection of cultures, accumulation of PHA and extraction of PHA. Once extracted, PHA is formulated to a compound to confer flexibility by using several additives, such as plasticizers, processing aids, UV-stabilizers, nucleating agents, etc. All these additives are bio-based products and have food contact approval. Once the formulation of compounded PHA were deeply study in a laboratory step to obtain two of the most suitable compositions and processing parameters for film blowing and foam injection, they were processed in semi-industrial equipment.

The results obtained in this work demonstrated the achievement of PHA based compounds from PHA generated from wastes with a competitive price and improved process ability for film blowing and foam injection. A preliminary techno-economic evaluation has reveal good perspectives for processing at industrial scale of 5000 tpy and even with cost reductions around 20% below the current market price.

EuroPHA project will innovate in three areas of PHA life cycle:

•PHA production by Mixed Microbial Cultures. This makes possible the use of low-cost feedstock which are agro-food waste/surplus effluents, with no market value and not competing with food, and are not affected by price volatility. It transforms a cost in a revenue.

•PHA extraction, isolation and purification. Using physical techniques for extraction and isolation, and environmentally-friendly chemical purification.

•PHA compounding into 100% compostable bioplastics (barrier film and foam trays) with >90% biobased carbon for food packaging. High quality food-grade bioplastics will be developed. These bioplastics can be disposed together with food and managed as organic waste by industrial composting and anaerobic digestion EU standards.
Project Context and Objectives:
Food requires optimal preservation by a packaging that must fulfil two requisites: high thermal stability (quality) and high barrier properties (safety).

•Non-renewable petrochemical plastics are used because of their low price and they ensure quality and safety of food. After food packaging is consumed, consumer dispose these plastics and it becomes a waste that is normally landfilled or burned, and it is not easily recycled.
•Today’s plastics films are multilayer systems, but they cannot be separated for recycling.
•Waste effluent management from food processing SMEs have become a time and cost-consuming issue.
•Current bioplastics lacks of low thermal stability (like PLA) of high producing costs (like commercial PHA).
•Commercially available PHA do not present the required performance to be industrially processed by film blowing and foam injection.
•European production of PHA plays a very small role (<10%) in the global market. Furthermore, US and China’s PHA production has severe limitations, due to the high cost of feedstock and pure microbial cultures in sterile conditions.

EUROPHA project could solve the above mentioned problems by means of the implementation of the next technical solutions:

•Composting and anaerobic digestion of bio-degradable food plastics would make the landfilling problem disappear.
•Consumers will be able to dispose the EUROPHA products together with food residues without needing separation.
•Low-cost waste effluents from SMEs could be used as feedstock to synthesize PHA and reduce its processing costs.
•EUROPHA tried to find a way to reduce the economic and environmental costs of extracting and purifying

PHA, with good thermal and barrier properties.
•Two suitable formulations have been developed for industrial processing.
•EUROPHA solution will improve the European capacity to use alternative feedstock and microbial conditions for PHA production.

EUROPHA partnership has been ideally placed to develop and exploit this technology. This project is a Research for Associations that will contribute to a wide dissemination and use to ensure that large communities of SMEs benefit economically from the project results.

EuroPHA consortium comprises: four Associations of industrial companies from four different countries: FECOAM from Spain, SPIF from Sweden, PLASTIPOLIS from France and BPF from UK.

It also includes 3 SME companies from 2 more different countries: IDRO from Italy and TECNO from Spain. Finally, it involves 3 RTD performers independent from each other and from any other type of participant to carry out the R&D work: IBET from Portugal, EMPA from Switzerland, and INSPIRALIA from Spain.

EUROPHA project looks for some scientific, technological and exploitation objectives:

Scientific objectives:

1. Analysis of low-cost agro-food waste/surplus.
2. Determining optimal PHA composition of monomers and molecular weight for bio-plastic films and foams.
3. Selection of bacteria in mixed cultures.
4. Characterization of PHA-accumulating microbial communities.
5. Study of combination of techniques that uses physical technique for cell disruption, non-PHA cellular matter removal and subsequent PHA isolation.
6. Volatile Fatty acids production.

Technological objectives:

1. More than 50-Litres scale PHA production pilot setup.
2. Production of intracellular accumulated PHA.
3. PHA extraction, isolation and purification.
4. PHA compounding for food packaging applications.
5. Validation of EuroPHA technology and products.

Exploitation objectives:

1. Protection of EuroPHA results.
2. Dissemination with DEMO products.
Project Results:
The actual developments obtained for each result after the execution of the EUROPHA project have been:

1. Different operational conditions affecting the selection of a mixed microbial culture with the ability to store PHA, namely, the feedstock composition, nutrient addition strategy, aeration performance and organic loading rate were optimized. That resulted in an enhanced PHA storage capacity.

2. The selection and accumulation reactors configuration were improved and the pilot plant (based on the results obtained from the optimization of the operational conditions) was semi-automatized. Thus, it was possible to significantly increase the OLR and the biomass concentration in the selection reactor, leading to an enhanced overall productivity.

3. It could not be selected a specific combination to optimize the method. Rather, factors closed to the combinations were selected which yielded the best values during the design of experiments. After this round of optimization, the most promising technique was selected. In addition, propylene carbonate was used for purification as a backup technique, showing satisfactory results in purity, but lacking the generation of pure product with a high yield. We also performed an extensive characterization of the material, using TGA, DSC, FTIR, GPC, optical appearance of the polymer, showing that the properties of the extracted material did not differ much.

4. It was possible to model every step of the PHA production process based on rules taken from the relationship of the input and outputs from previous experiments made with sugar cane molasses mainly made by IBET. The strategy of using the decomposition of the masses of the components for each element turned out to be a powerful method to check the consistency of the models.

5. By transferring the technology of PHA production to a pilot plan, it was reached an improvement of the operation parameters, such as, specific PHA storage rate, specific consumption rate, yield of PHA during Feast phase, and also the specific X growth rate during Famine phase. Furthermore, the obtaining of a semi-automatize production stage, with also remote access and panel PLC communication was achieved.

6. PHA synthesized in laboratory showed the same biodisintegration rate as the commercial PHA; regarding the HB/HV ratio, the higher the HB percentage, the slower the biodisintegration activity; no relevant effects on biodisintegration were observed in the formulations due to the presence of foaming agents, natural processing aids or antimicrobial additives; and in terms of biodisintegration rate, commercial PHAs showed a fast and aggressive behavior.

7. Two optimum formulations were designed for both planned industrial processing: film blowing and foam injection. The formulations were always based on PHA and the required additives to fulfil the technical specifications of the application. All the additives have been selected trying to maintain the main objectives of low cost, food contact approval, availability and bio-based content.

8. Both formulations for film blowing and foam injection based on EUROPHA material were processed by extrusion, and samples of film and foamed items were obtained.

9. It was possible to affirm that biodisintegration in anaerobic conditions as well as in soil occurred for the sample of the EUROPHA material. Barrier properties, migration test, food contact approval and

antimicrobial activity were devised to validate the performance of the packaging systems based on the EuroPHA compounds for food packaging.

10. Techno-economic feasibility of EUROPHA technology has been performed and after analysing the operating cost and the investment cost for industrial plants it has reveal a preliminary profitability above 2500 tpy of PHA production for current PHA market price and 5000tpy considering a reduction of around 20%.
Potential Impact:
Potential impact on Food and drink sector.
A technology like EuroPHA will give double benefits to European food industries:

•Waste water reduction cost: Waste-water needs to be managed as a waste, but EUROPHA will reduce waste/surplus management cost by resulting in a high added value PHA biopolymer contained in the bacterial sludge.
•New compostable packaging: Own sugar-rich waste effluent will be converted them into fully compostable PHA bio-plastic that can be used to pack their own food products, improving their competitive advantage and contributing to solve the European problem of plastic waste.

Potential impact on EU society
Regarding the benefits for EU society:

•Food packaging with PHA bioplastic is a strategic action for the EC. The EC strategy “Innovating for Sustainable Growth: A Bioeconomy for Europe” aims at partially reducing the current EU dependence on non-renewable resources (as high as 84.5%) by the use of bio-based materials like bioplastics.
EUROPHA has proved a new source from PHA to be used, so we expect we can compete in price with petrochemicals.
•PHA matches consumer and manufacturer needs better than competitors. For the market of food and beverage packaging, PHA matches the trends better than petrochemical plastics and bio-based alternatives (PLA and starch):
-Avoiding costs risen for food raw materials: raw materials for bioplastic production has been switch from current sugars (from edible crops like corn, beet, and sugar cane, used for PLA, starch and current PHA) to low costs non-edible sources, such a food industry wastes.
-Consumers are attracted to green, safe and healthy food products. PHA bioplastics will match these requirements: it is 100% bio-based from non-edible sources, 100% compostable as certified by the EU standard EN13432 and it can be effectively processed by current plastic transforming techniques.
-Convenience drives food to-take-away that can be disposed. In our busy world consumers will pay a premium for convenience, like eating quality food on the run and disposing packaging and food leftovers altogether. This trend will make sorting and separation of plastics increasingly difficult for recycling. Compostable bioplastics like our PHA formulations reach prepared food markets (that can require pasteurization or need to be hot filled) and bottles of carbonated beverages (soda containers require excellent CO2 barrier). PLA is CO2 permeable and deforms at >60ºC. PHA withstands 150ºC and is a barrier to CO2.

Potential impact on participants

FECOAM’s members. Thanks to the project, they will save 60% of waste management costs. In addition, since the packaging and leftovers made with PHA are compostable and disposable jointly to the waste food, it represents a drive force for customer acceptance, increasing the sales of packaged food by a 15%.

On the other hand, PHA production from waste/surplus is financially attractive for agro-food SMEs. When comparing the life cycle assessment (LCA) and financial features of PHA production by mixed microbial cultures using agro-food waste/surplus as raw material (EuroPHA approach) with its main competing technology, the anaerobic fermentation of agro-food waste for biogas production (competitor for raw materials), the first one is expected to have an Internal Rate of Return of >25% compared to the second one by full anaerobic fermentation (IRR <7%). For a similar feedstock the kg of valuable PHA polymer is 3 times higher of the value of kg of biogas.

BPF, PLASTIPOLIS and SPIF’s members. Bio-based and compostable PHA packaging meets the need of SME companies to prove a true commitment with resource sustainability.

TECNO and IDRO will have opportunities to strengthen their current market position, increasing shares in their respective markets, entering new markets, and also increasing their competitiveness with added values derived from the acquired new knowledge. They will benefit from manufacturing and selling the EUROPHA technology to the SME-AG members increasing their turnover and profits.

Dissemination activities
Relevant dissemination actions where EUROPHA has been exhibited are shown below:

•Press release: has been delivered to specialized reviews and newspapers to announce the start of the project and the beginning of the research program. Other press releases are going to be launched to specialized reviews and newspapers to announce the main technological developments.

•Newsletters and bulletins have been produced as dissemination materials mainly directed to growers and involved parties.

•Posters: submitted to European congress and symposiums, such as 6th European Bioremediation Congress, 8th European Symposium on Biopolymers, 15th International Symposium on Biopolymers, 10th International Symposium of Environmental Biotechnology, etc.

•Conferences: held and attended by consortium members, such as Plastipolis Forum, 3rd Edition of MATBIM, Seminar of Biopolymers (AIITIP-Spain), FP7 Dibbiopack Conference, CIRCE workshop, etc.

•Video production: a dissemination video presenting the project and results was realized by SPIF. The video was uploaded on the Website.

•Meetings to End-Users, such as online workshop with Plastipolis members.

•Especial dissemination meetings, such as SPIDO tradeshow, Fakuma tradeshow, etc.

•Project web site for the dissemination of EUROPHA activities outside the consortium updated every 3 months. The contents have include a home page with the project presentation and objectives, consortium members, a news section, project information and a Demo video. Partner´s web site is another way of dissemination of Project life and events.

Exploitation of results
There is a main route for the exploitation of this novel product. Sequential exploitation strategy has been designed:

•Year 1: stablished in composting/digestion countries such as Sweden, The Netherlands, and Italy, because these are the natural markets of SPIF and IDRO.

•Year 2: stablished in composting/digestion countries such as Germany and Austria. Besides, Switzerland and Norway which are other geographically close countries with a separate collection of wastes for composting/digestion. Year 1 experience will be optimized here.

•Year 3: countries with composting in implementation: UK (natural market of BPF) and Belgium.

•Year 4: countries with composting in preparation and France (natural market of PLASTIPOLIS).The experience accumulated during the previous three years will help prepare us to penetrate in these not so mature markets.

•Year 5: Spain (natural market of FECOAM). We will follow the same strategy as in Year 4 but now counting with FECOAM as the partner with a prominent role and responsibility.

•The order of expansion is in accordance with the market dynamics: those countries that may consume bio- plastics but does not compost will most probably follow the composting pioneers with a 2-3 years delay. Thus, by the time these markets are conquered (Years 4 and 5) they will be ready to uptake EuroPHA.

The strategy of exploitation and dissemination has comprised the next key points:

•Identification of project results and relevant IP (intellectual property) to be derived: results of the project were presented in previous section 2.

•Distribution and/or ownership of foreground IP between partners. This distribution was presented in previous section 3.2. The following principles are applied with regard to exploitation of results, which includes use and dissemination, from EUROPHA project:

-The SME-AGs (FECOAM, BPF, PLASTIPOLIS and SPIF) will keep shared ownership of the three results. Each will own 25% of the three results.

-The subcontracted RTD performers, (EMPA, I-BET and INSPIRALIA) are expressly prevented from owning any of the resulting foregrounds from the project.

-There are no existing anticipated business agreements which may impose limitations on the subsequent exploitation or information or inventions generated as a result of the project.

•Updated patent analysis of the market to be penetrated and identification of competing patents. Revision of publications and patents during the project that may affect the exploitation of the project's results will be carried out.

•Establish a marketing strategy.

The Exploitation Model has covered the following actions:

1. Protection of foreground knowledge. Patent search has been carried out during the project to ensure that the developments by the EUROPHA consortium are not affected by other potential competitors and products in the targeted markets. The protection of the knowledge could be done through patenting of each of the main results arising from the research. However, there are other ways of protection the knowledge, less stringent and cheaper: utility model, trade secret, etc.

2. In order to design the best marketing strategy to allocate commercial efforts initially at largest demand regions, an Assessment of European and world-wide markets demand study will be done.

3. Product cost characterization study has been performed. This study has performed the quantitative and qualitative evaluation of potential markets, the associated cost in the production of raw PHA and PHA final formulations. Product cost characterization has been one of the central issues of the project, taking into consideration that providing for a new process and a new material has a competitive bearing only when this may guarantee competitive terms of commercialization.

4. Public Access to the EUROPHA results will be available by agro-food, organic waste and bioplastics (compounders and processing) sectors. The way to transfer this knowledge has been by the publication on commercial journals and magazines proposed by the SME-AGs and SMEs previously approved by the Consortium in order to prevent that those publications does not affect the exploitation of non-protected results of the project. RTDs have plans to publish a number of academic articles, and has presented posters and comunications to conferences. These materials were confirmed for publication by the partners.

5. A web based portal is designed. The web portal has two different versions. The public part will be providing basic information for the public interested third parties are able to visit the website and acquire valuable information for the project, while a private (coded) version is available to the project partners in order for these to communicate with each other and in order to save there materials that are not public but of core value to the project.

6. Dissemination and commercialization of the technology has been and will continue to be ensured by exhibition in international trade fairs, exhibitions and conferences.

Partners to the project have been very active in communicating information about the project, and the preliminary results. This process will be continued after the completion of the project. This will also be one of the basic channels for acquiring commercial contacts and providing for the commercialization of the end-results. In order to preserve the value of the project results and maintain the possibility to acquire license-fees the description of the project-results should be proceeded into an as much as possible level and not provide details that should only be made available to commercial partners, under the terms of commercial agreements.
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Documenti correlati

final1-europha-final-publisable-summary-report-final.pdf

Ultimo aggiornamento: 16 Novembre 2017

Permalink: https://cordis.europa.eu/project/id/604770/reporting/it