whey pack

PHB-based packaging from whey

REDUCTION OF CO_2 EMISSIONS BY THE PHB USE OBTAINED FROM WHEY

A project funded by the European Commision under the LIFE programme

LIFE13 ENV/ES/000608

www.wheypack.eu

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1. PROJECT CHARACTERISTICS

Programme: Life programme - LIFE13 ENV/ES/000608
Duration: 01/06/2014 – 31/07/2017
Budget: 1.188.777 € (EU contribution: 50 %)

2. PARTNERS

WHEYPACK project has been performed trough a cross border collaborative project (Spain and Portugal) with a multidisciplinary human work team with high experience in food technologies and production, bioprocess technologies, microbiology, physical-chemical analysis, polymer technology and food packaging manufacturing.

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3. CONTEXT AND BACKGROUND

Main challenges and motivations facing the project:

I. European Union committed to the environment.

Currently, about 11% of all greenhouse gases emitted into worldwide correspond to the European Union, and there is a firm commitment by the EU to reduce its emissions by 30%. WHEYPACK development project is aligned with this reduction commitment agreed by the European Union in its strategic policies.

II. Valorization of whey surplus.

Whey constitutes a surplus material from dairy and cheese industries. The cheesemaking process generates, on average, for the production of one ton of cheese, 9 tons of whey.

Nowadays, the amount of whey produced, especially in the EU-27, surpass by far the food industry requirements. Only in Europe, it is estimated an annual production of 75 million tons of whey from cheese makers. Although some of this product again returns to the food chain for the production of other dairy products, a great part of whey is discarded and needs to be managed.

Hence, whey constitutes a surplus material even causing severe disposal problems for dairy industry. In that sense, an even larger surplus exists, and alternative solutions have to be developed.

Whey is composed primarily of water (approximately 85%) and contains more than half of the solids originally present in the milk, including 1% protein (20% of total protein), the major part of the lactose (between 4 and 5%), minerals (1%) and water-soluble vitamins, so it has great potential for use in other applications.

In the WHEYPACK project we have studied the technical feasibility of the bioconversion of whey into polyhydroxybutyrate (PHB) by a fermentative process by microorganisms as an alternative for the recovery of this product.

PHB bioproduction process

III. Bioplastics more sustainable.

Today, Europe produces more than 70 million tons of plastic waste, mostly from packaging, which generate a large carbon footprint. Petroleum based plastics, thanks to their performance and low cost are often used for the production of containers for single use or not reused, being most of them of difficult biodegradation. Studies conducted on the forecasts of waste generation in Europe by 2035 indicates that the plastics sector has the greatest potential to reduce the environmental impact of waste. This has aroused the need to investigate the development of more sustainable packaging.

Consumer interest in biodegradable and bio-based materials has grown as a consequence of increasing social awareness of the power to reduce environmental impacts by selecting more environmentally-friendly products. There is a global trend toward the development of sustainable packaging using bioplastics. Although the market is still dominated for over 99% by petrol-based plastic, there is an emerging and growing market for bio-based plastic produced from renewable resources.

Bioplastics, in certain applications, are able to reach values in their properties on the order of traditional polymers. In this regard, PHB is a completely biodegradable biopolymer that belongs to the family of polyhydroxyalkanoates (PHAs), which is synthesized and accumulated intracellularly by some microorganisms as a source of carbon and energy, under unfavorable growing conditions. PHB can be processed as a classic thermoplastic showing properties very similar to those of polypropylene (PP). PHB is an interesting biopolymer because of their good properties: It is biodegradable, compostable, comes from renewable sources (bio-based) and could feature similar to those of traditional polymers from petroleum, such as the PP.

4. OBJECTIVES

I. General Objective.

WHEYPACK project wants to demonstrate that carbon footprint of manufacturing process of PHB-based packaging is lower than current manufacturing processes of PP-based ones.

II. Specific objectives.

O1 Demonstration of the environmental, technical and economical feasibility of PHB based packaging manufacturing processes from whey, considering all the chain steps involved in this industry so closing a loop: 1) PHB bioproduction from whey, 2) polymer compounding, 3) PHB-based package manufacturing and 4) use by the cheese maker at a small scale.

O2 Demonstration that total greenhouse gas emissions (carbon footprint as CO_2 equiv.) of the production process is lower than current manufacturing process of petrol-based food packages (polypropylene, PP).

O3 Definition of the PHB bioproduction and recovery processes from whey at pilot plant scale. Study of the scale up conditions from pilot plant to industrial scale.

O4 Formulation, compounding and adjustment of the PHB polymer in order to improve its processability properties for injection moulding process

O5 Development of 100% biodegradable PHB-based packages (bowls) and demonstration of their application to dairy products: cheese packaging.

5. WHEYPACK PROJECT METHODOLOGY

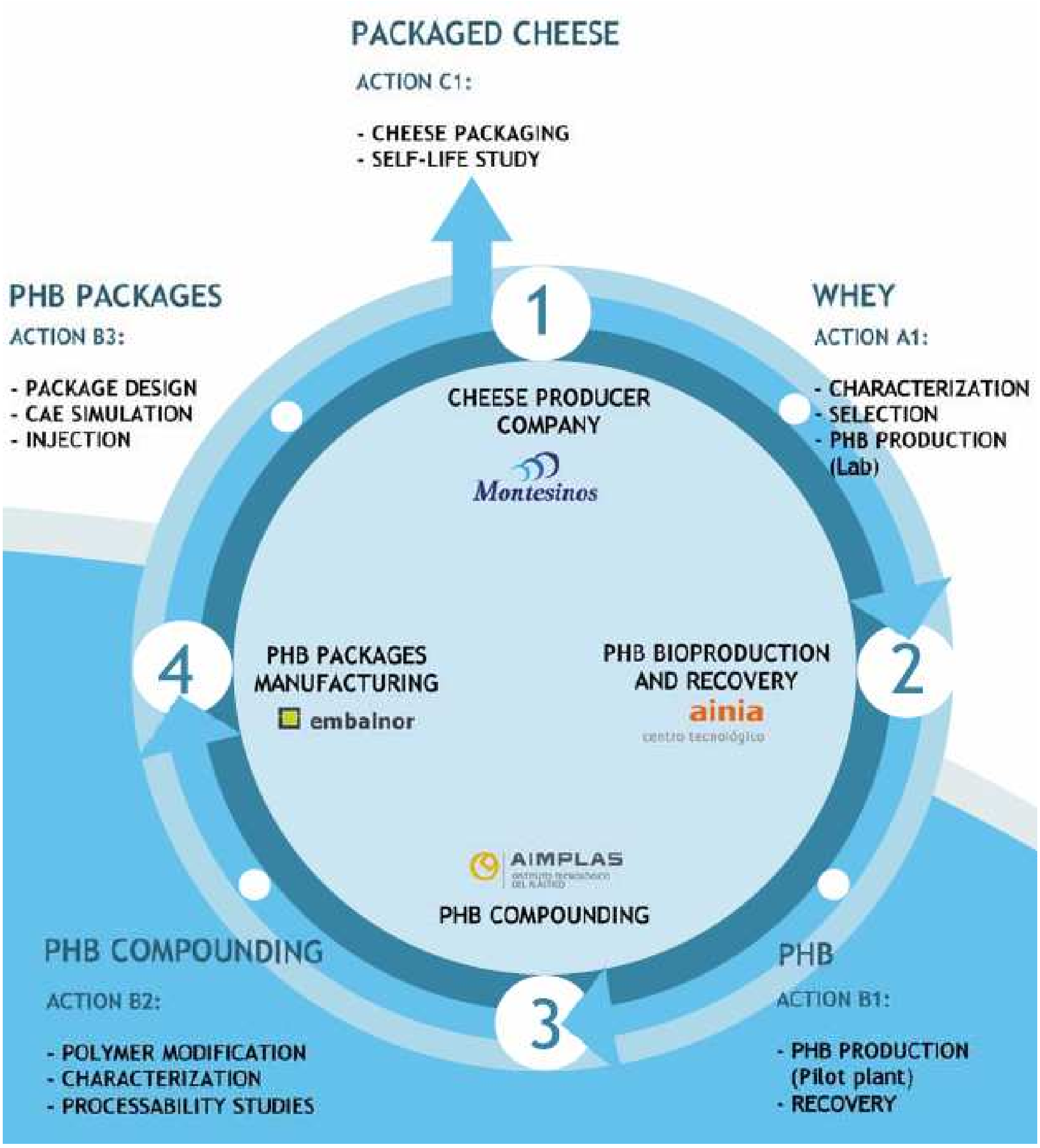
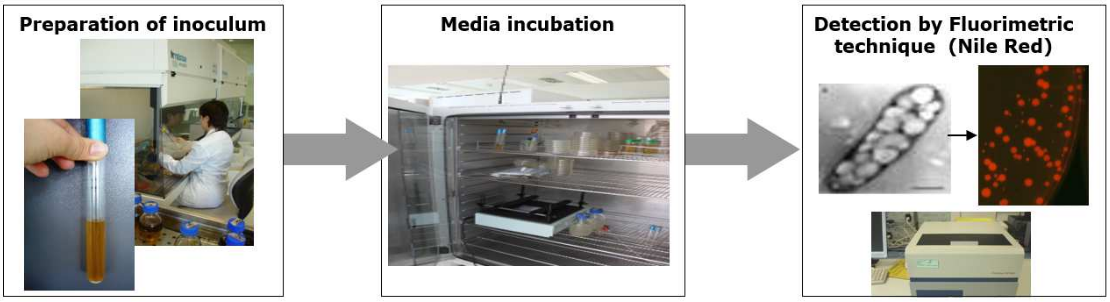


Diagram of WHEYPACK project

The following **actions** were developed to achieve project general and specific objectives:

I. Production of PHB from whey through the application of bioproduction technologies

The first step of the project work plan consisted in the characterization of the different types of whey obtained in the preparation of different cheeses, and selection of better based on their skills as culture media for microorganisms.



Experimental design of laboratory scale tests.

The selection and acquisition of overproducing microorganism PHB has been made based on literature. The selection criteria were: PHB production from whey (ability to use lactose as carbon source), high performance short culture period and their availability in international collections of microorganisms.

PHB production in 2L bioreactors.

Tests at laboratory scale and pilot plant scale have been carried out to adjust bioprocess conditions in order to achieve the higher PHB production.


PHB production in 200L bioreactor.

Finally, with all the information obtained from pilot plant scale, the scale-up of the process to industrial scale was calculated.

II. PHB polymer modification and compounding in order to obtain a final PHB-based material which can be processed by injection moulding technology.

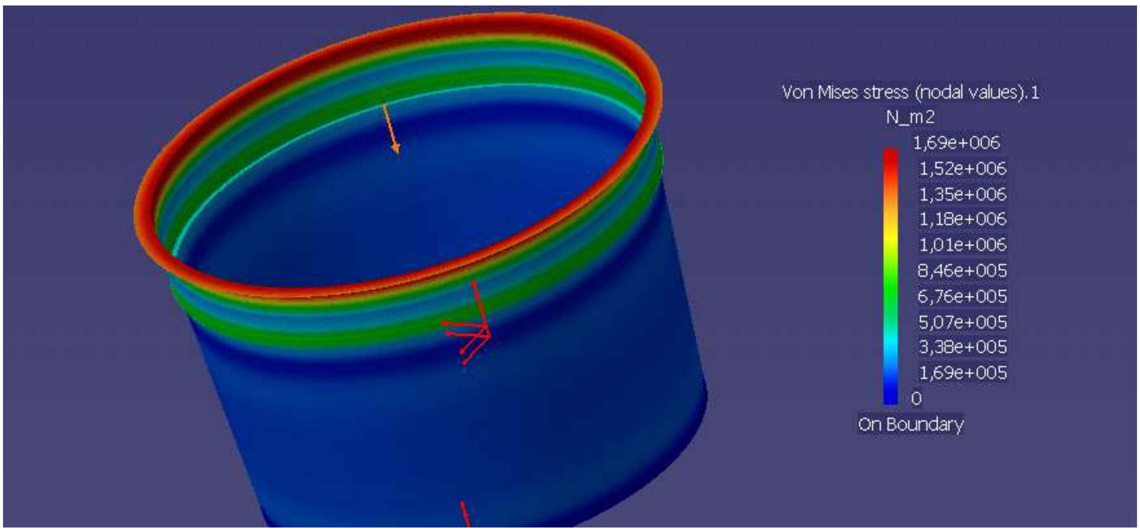
Characterization, formulation and additivation of PHB was performed to improve PHB based material properties in order to be processed using the same technology (injection moulding) and existing equipment that are currently used to produce PP based packages.

An exhaustive study was carried out to select the optimal additives (in accordance with European food contact materials legislation) to protect the polymer degradation and to improve their processability, such as antioxidants, plasticizers, release agents, lubricants and nucleating agents.

WHEYPACK PHB based compounding

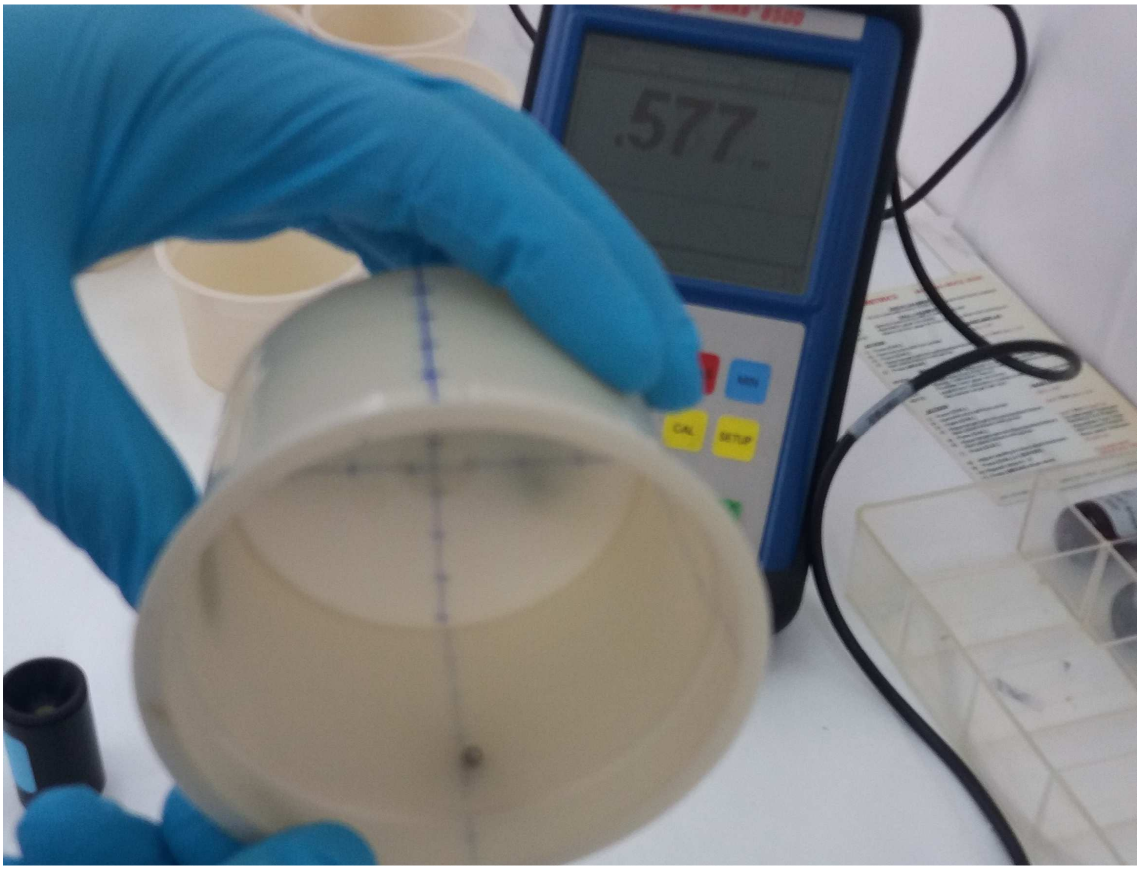
III. PHB-based bowls have been produced by injection moulding technology.

On one hand, preliminary studies about the injection process were developed to improve the performance of the package, and also focused on conceptual studies and product engineering in order to be able to process the PHB compounds. Potential problems that need to be taken in consideration were identified.



PHB based package CAE simulations

On the other hand, it has been identified the characteristics needed in the packaging in order to warranty the quality and the protection of the product, along its shelf-life. Characterization of mechanical, chemical, barrier and thermal properties of the PHB based packages was done.



PHB based package characterization

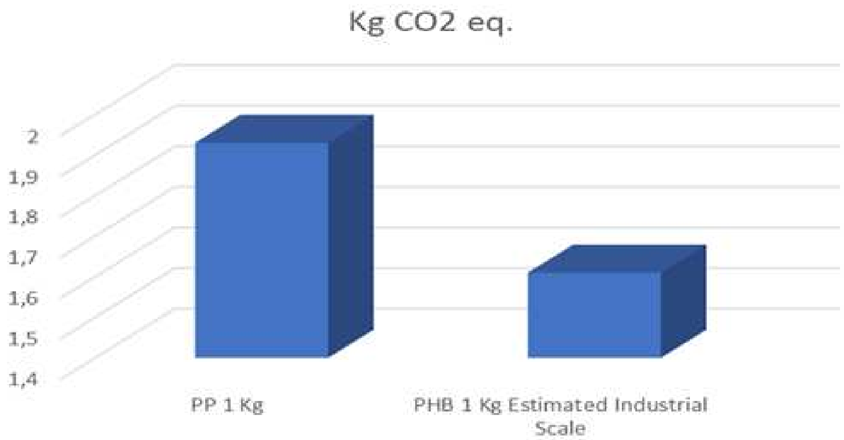
Finally, applicability of developed PHB-based package for cheese packaging was carried out with corresponding shelf-life studies of packaged cheese.

IV. Monitoring of the impact of project actions

During the whole project development, environmental, technical and socio-economical assessment has been performed.

6. RESULTS ACHIEVED

R1 Reduction of 16%* of the total carbon footprint **(*estimated scenario at industrial scale)** of the PHB-based packaging manufacturing processes (using whey), taking as reference the PP-based packaging manufacturing ones.



Comparison between CO2 emissions associated to the production of a Kg of plastic material.

R2 95% reduction of the BOD (biological oxygen demand) and 95% of the COD (chemical oxygen demand) of "industrialized" whey (after its use for PHB production) when compared with original whey.

R3 Eco-efficient viability of PHB bio-production processes from whey.

R4 Manufacture by injection moulding process of 100 % biodegradable packages (bowls) based on PHB polymer obtained.

WHEYPACK PHB based package

The developed PHB based package complies with the properties demanded by the application for cheese packaging, its thermal, mechanical and barrier properties are similar to the reference material (PP).

Despite raw PHB could be used for food packaging, based on the results of overall migration and specific migration analysis, the developed PHB based (aditivated PHB) package can not be used for food contact (Commission Regulation (EU) No. 10/2011).

New compounding and aditivation studies must be performed in order to allow the developed PHB based package to be used for food packaging.

However The material obtained has a great potential for non-food applications that require thermal and impact properties, especially at low temperatures that could be exploited in new applications.

7. OUTCOMES AND LONG TERM BENEFITS

WHEYPACK project has demonstrated that carbon footprint of manufacturing process (estimated industrial scale) of PHB-based packaging is lower than current manufacturing processes of PP-based ones.

To achieve this, WHEYPACK project has been divided into two main processes: fermentation process for obtaining PHB material from whey and bioplastic injection process for obtaining food packaging.

- Regarding to the fermentation process, WHEYPACK project has demonstrated that the production of PHB from whey could have a lower carbon footprint than the current process for plastic production from fossil sources. Additionally, WHEYPACK project has demonstrated that this process could be both economical and environmental efficient and it could be used as an alternative for whey disposal in all European dairy food industry.

- Regarding to the injection process, WHEYPACK project has demonstrated that current manufacturing processes of polymeric packaging can be used for obtaining bioplastic packaging without increasing the carbon footprint of the whole process.

One of the main barrier affecting the extent of the use of bioplastics from renewable sources in general, and PHB in particular, it is its high cost, between 2 and 4 times higher than other traditional petroleum based plastics.

This is largely due to the fact that most of bio-based plastics coming from renewable sources, use carbon sources such as corn, potato, sugar cane or rice, among others.

WHEYPACK has demonstrated that whey can be used as raw material for biopolymers production and it could contribute to reduce the PHB cost.

This solution performs better from energy, greenhouse gas emission and ethical perspectives: agricultural inputs and activities are avoided, as are indirect consequences of using crops for producing bio-based materials, such as direct and indirect land use change, and also prevents the utilization of various renewable feedstocks that can be used for food.

WHEYPACK could help to decrease the need for valuable raw materials which can be intended for food, with consequent better use of renewable resources from the ethical point of view.

On summary WHEYPACK project has the potential to diminish the use of non renewable fossil fuels for plastic production and related petroleum dependence as finite resource, decrease CO2 emissions and reduce plastic waste.

WHEYPACK project is directly related with two of the most important manufacturing sectors in the EU: food and food packaging sectors. In that sense, the project will have positive environmental and socio-economic effects all around the European Union.

The WHEYPACK results of the project are widely applicable and easily transferable to any European Member and could have a market replication in other kind of products manufactured by injection process.

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