
# PROJECT FINAL REPORT

## Final Publishable Summary Report

**Grant Agreement number:** 304987

**Project acronym:** DEGRICOL

**Project title:** ***Consumer-safe and thermally stable bioplastic formulation with controlled biodegradation properties for agricultural and horticultural accessories***

**Funding Scheme:** FP7-SME-2012-1

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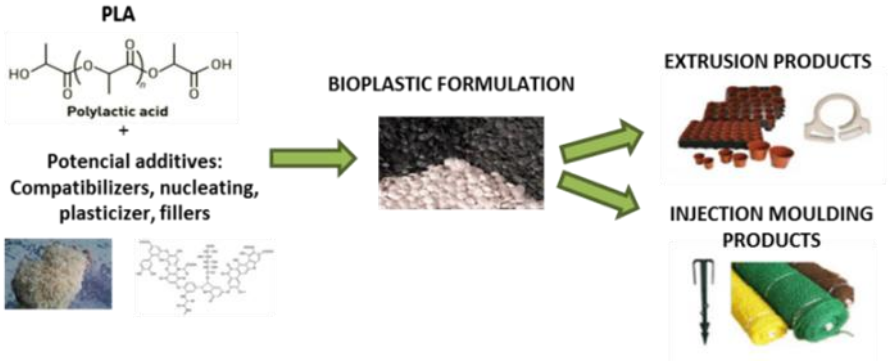
[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

# Table of Contents

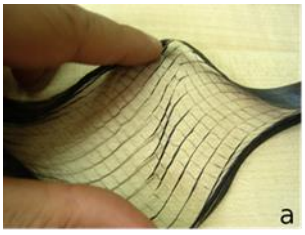
# 1. Executive Summary

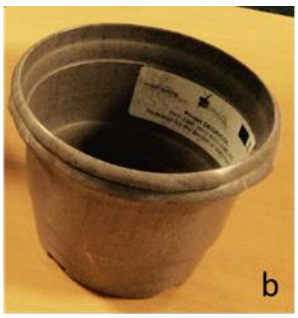
In DEGRICOL we seek to develop a 100% natural and biodegradable bioplastic formulation for the manufacturing of injection-molding (pots and clips) and fiber-extrusion (nets and tutors) accessories for agricultural and horticultural applications. DEGRICOL project aimed to develop a PLA-based matrix with high thermal stability and controlled biodegradation in the product phase. In addition, this biodegradable accessories must be consumer-safe so, the study of the migration levels was necessary.




It was very challenging to succeed to all technical points proposed in the project, and we can summarize the results as follows:

- Molding parts: we develop a formulation suitable for injection, and injection-compression-molding, that respect the technical product specification, and it is processable
- Extrusion part: we develop formulation suitable for this specific tape-fibrillation-extrusion process. The processability should be enhanced by changing some machine specification (Increase rolls diameter, change the hot table by an oven)
- Consumer safe: no toxicity have been shown on the testes sample in biodegradation
- Controlled biodegradation: we demonstrate that the surfactant (component to control degradation) didn't affect the mechanical properties of the compound, and we have sorted the different bio-surfactants regarding the aptitude to increase bio-degradation.
- Bio-based compound: the initial target was 100%, but we only reach 60% to 70%. The highest level can be obtained by injection-compression molding.




The work developed has included the following achievements:

- We search for potential natural compounds to be used as fillers in the matrix of PLA. Three different organic fillers form natural waste were selected: almond shell, olive stone and wood flour.
- We search and selected 2 types of PLA: for extrusion (PLA 6400D) and injection moulding (PLA 3251).
- We studied the compatibility of up to 3 fillers within 2 types of PLAs, as well as other natural inorganic fillers of different chemical composition, geometry and/or size.
- We analysed the effect of addition of other bio-polyesters, including those with functional properties (thermal conductivity, anti-blocking, etc).
- We design different formulations for the 2 types of PLAs and processes.
- We prepared mixtures of those components by extrusion and studied the mechanical and thermal properties of those compositions.

- We optimised the processing conditions for the compounding of these formulations: Several degassing zones were included to avoid molecular weight decomposition.
- We performed several industrial extrusion trials at the site of partner Rodenas & Rivera, to get insight in the production process, possible bottlenecks and figure out them to manufacture proper tutors. Likewise, several formulations with different compositions, varied taking into account the conclusions from the previous ones, were tested in the Rodenas & Rivera facilities and equipment.
- In like manner, many other industrial trials were developed regarding the injection formulations, with the aim of produce flower pots with adequate mechanical performance and suitable thickness.
- The finished products: tutor (a) and plant pot (b) were tested to ensure the final quality of use. The mechanical and thermal properties have been evaluated; FTIR analysis has been carried out and the internal matrix has been studied with a scanning electronic microscope.
- We carried out a biodegradation study on the developed formulations and products (tutors and pots) focusing on biodegradation in soil.

In summary, in terms of performance we may report in DEGRICOL we have obtained two specific formulations suitable for production of pots and two suitable formulations for production of tutors. Several pots could be produced with these formulations. Although the extrusion formulations are not stable enough to produce tutors in a continuous way. Nevertheless the tape can be fibrillated and tutors can be obtained. The tutors can be used in horticultural facilities. As negative aspect we have to point than tutors do not achieve the same mechanical strength that tutors made of R-PP.

# 2. Summary description of project context and objectives

Existing bio-based and biodegradable materials still have serious limitations on cost and product performance compared to conventional plastics, such as polyethylene (PE) and polypropylene (PP), which are non-expensive and resistant to degradation. Both of them are non-biodegradable and petro-based materials. Although the prices of these plastics have increased up to 70% during the past years due to high crude oil prices, so far bio-degradable plastics are still not affordable making them unacceptable to growers. In addition, these plastic manufacturers are facing strong production competition from big enterprises from Asia and Brazil. For this reason, and in order to help the EU bioplastic sector competitiveness, it is essential to develop bioplastic materials at lower total cost with added benefits to the end-users. Competitive pricing will also facilitate the acceptance of the material's eco-benefits.

Agricultural plastic waste, which is left on the ground next to the crops (landfilling: 0,67 MT/year in EU) or burnt uncontrollably by growers (incineration: 0,37 Mt/year in EU), produces the release of harmful substances. The presence of plastic particles in soil that have a negative effect on soil quality and water retention

The main problem of conventional plastic products used for agriculture and horticulture is the disposal methods that are used to get rid of them. From the 1,231 Mt of agricultural plastics waste produced by EU members in 2008, 21% were treated through mechanical recycling, 25% through energy recovery or burning, and 54% are placed in landfill or buried. Sending agricultural plastics to landfills is not a viable solution due to its high cost, as well as the fact that conventional plastics take 100 to 400 years to break down if ever. When incinerating or burning plastic waste, in addition to $CO_2$, different toxic particles are produced going to the atmosphere as fume. Agricultural plastics are contaminated also with residues of earth and chemicals products from plant treatments such as pesticides. To keep the atmosphere free from these particles, the fume should be treated in a complicated, delicate and costly process. The case of mechanical recycling is not suitable for agricultural plastic wastes since adds further steps to the recycling process and it is only applicable when the plastic waste is highly homogenous, that is not the case.

As mentioned above, the consumption of plastic material in agriculture and horticulture in EU has dramatically increased in the last decades, posing serious problems of environmental and economic concerns. The recycling of this products is very expensive and a time-consuming activity due to the high labour cost for the collection and the impossibility to be automatized. If this is not well regulated farmers could tend to burn or landfill the residues.

The substitution of non-biodegradable plastics by biodegradable polymers arises as a good alternative, and poly (lactic acid), PLA, is the most widespread biopolymer.

However, PLA shows some drawbacks:

- Brittle material with poor toughness.
- Susceptible to degradation during processing due to humidity.
- Low HDT, related to its low glass transition temperature.
- Not soil degradable.
- High price, compared to "commodity" polymers.
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In that sense, the 100% natural-based bioplastic formulation based on PLA matrix should overcome these drawbacks by means of different additives to improve its performance. In particular, bio-fillers derived from renewable resources have attracted a great deal of interest for the reinforcement of PLA due to their sustainable supply and environmentally benign production, and can be a cheaper substitute for synthetic fibers, such as glass and carbon. They have more advantages, such as low cost, low density, high toughness, acceptable specific strength properties, ease of separation and also biodegradation. Despite of all these achievements, the main drawback of natural fibers may be their hydrophilic nature, which decreases the compatibility with hydrophobic polymeric matrices.

The objective of the DEGRICOL project is to develop a 100% natural and biodegradable bioplastic formulation for the manufacturing of injection-molding (pots and clips) and fiber-extrusion (nets and tutors) accessories for agricultural and horticultural applications. DEGRICOL project aims to develop a PLA-based matrix with high thermal stability and controlled biodegradation in the product phase. In addition, this biodegradable accessories will be consumer-safe by studying the migration levels, and developing if necessary specific tests.

# 3. Description of main S & T results/foregrounds

The expected final results within DEGRICOL project are:
1. An integrated bioplastic formulation 100% biodegradable and compostable according to the official EU standards used to certify that a material is home compostable.
2. An integrated PLA-based formulation for the manufacturing of injection-molding bioplastic products for agricultural and horticultural applications.
3. An integrated PLA-based formulation for the manufacturing of fiber-extrusion bioplastic products for agricultural and horticultural applications.
4. Bioplastic with controlled biodegradation under home composting conditions through Humic acid-like surfactants.
5. Consumer-safe biodegradable PLA-based plastics accessories for agriculture and horticulture according to EN 2007/19/CE for food contact and ISO/DIS 11269-2 and ISO 11268-1 for no eco-toxicity and compost quality testing of biodegradation in soil

The DEGRICOL project has developed two biodegradable formulations suitable for extrusion and injection. Tutors have been developed from an extrusion process and pots have been developed from an injection process. The Finished tutors and pots have been tested to ensure the final quality of use. Mechanical and thermal properties have been evaluated and also biodegradation in soil burial.

It was very challenging to succeed to all technical points proposed in DEGRICOL project, and we can summarize the result as follow:

- We have developed a formulation suitable for injection, and injection-compression-molding, that respect the technical product specification, and it is processable.
- We have developed a formulation suitable for this specific tape-fibrillation-extrusion process. The processability should be enhanced by changing some machine specification (Increase rolls diameter, change the hot table by an oven)
- We have shown the no toxicity of the products.
- We have demonstrated that the surfactant (component to control degradation) didn’t affect the mechanical properties of the compound, and we have sorted the different bio-surfactants regarding the aptitude to increase bio-degradation.
- Although the initial target was to obtain a 100%, biodegradable formulation, we could only reach 60% to 70%. The highest level can be obtained by injection-compression molding.

# 4 Potential impact and main dissemination activities and exploitation results.

Through the new developed formulations the European agricultural-horticultural professionals will benefit of affordable biodegradable accessories and thus eliminating the waste management costs. Consequently, farmers will increase their margin benefits of their production activity, becoming more competitive and less dependent to national and EU subsidies. In addition, DEGRICOL products will be cost-competitive solutions and thus European bioplastic sector will be able to compete with petro-base accessories.

PLASTIPOLIS will have access to the innovative material formulation for the biodegradable plastic accessories and increasing the competitiveness of the bioplastic sector by offering cost-competitive and efficient agricultural products in comparison with petro-based competitors and the bioplastic existing already in the market. PLASTIPOLIS will strength and knowledge transfer innovative materials to their members. Regarding IPR, PLASTIPOLIS will share the IPR generated after the project with the rest of Associations in the Consortium. PLASTIPOLIS will act as Bioplastic sector End-User in the supply chain

TZOB will have access to the developed agricultural accessories that will help to the agricultural sector by offering affordable products and 100% compostable materials eliminating the high costs for plastic waste collection since it will not be necessary anymore. An impact at European level will be made through the execution of an exploitation plan to optimize the generated results. Regarding IPR, TZOB will share the Intellectual Property Rights generated after the project with the rest of Associations in the Consortium. TZOB will act as Agricultural sector End-User in the supply chain

MGH will have access to the developed methodology that will help to the agricultural sector to be safe about their products in contact with biodegradable materials during crop growth. Regarding Intellectual Property Rights, MGH will share the IPR generated after the project with the rest of Associations in the Supply Chain of the Consortium.
The technology that will be developed during the project will allow BIOPAC to be competitive in the European bio- products sector, in the face of great pressure from overseas competition which is developing new bio materials and expanding output of existing bio materials. Significant business growth through the sales and distribution of agricultural bio-products from exclusive access to (and thus availability of) Biopolymer at competitive commercial rates and sustainable differentiation within the market place through unique materials.

BIOPAC will increase their port-folio of bio-plastic formulations. Regarding IPR, BIOPAC will have royalty-free license for the results generated from the Associations of the Consortium.

Apart from environmental benefits the production of DEGRICOL bio-based polymers, it is also expected to have positive socio-economic effects particularly in relation to employment in the agricultural sector. Assuming that European agricultural land its progressively being abandoned due to the decline in Agri-food sector in Europe, then the production of bio-based polymers leads to increased employment in the cultivation and harvesting of starch and sugar crops. Employment in agriculture is expected to increase if Policies and Measures are taken in EU that include the promotion of land use to bio-resources for bio-polymer production such as DEGRICOL products that it is the most likely case.

We tried to explore the current state of the art in terms of patents in order to determine if we have a Freedom to Operate for the five valuable results depicted in the DoW (description of work). We finally decide within the consortium, not to patent the results, but to remain them secret and shared between the AG-SMEs and the SMEs. The first reason is that we didn't prove completely that our formulations are Soil Degradable, which is the most important result of this project. The second reason, is that we prefer not to explain the work do worldwide within a patent. With the ag-SMEs members, we will share some good practices and results under confidentiality. So they can made actions such as testing or commercializing a product without infringing valid intellectual property rights of others.

Some dissemination activities took place during this period:

Internal dissemination of the gained foreground: transfer all relevant know-how, foreground and results of the project from all partners (in especial RTDs) to the SME-AGs members to enable the appropriate application and use of the new edible coating. Provide complete documentation of product specification, application guide and risk assessment report and health and safety manual.

External dissemination activities. The DEGRICOL products have been disseminated along Europe aiming the facilitation for the implementation and exploitation of the process on industrial scale.
DEGRICOL Consortium aims to penetrate in national and European markets carrying out a series of dissemination actions. SME AGs started to identify the stakeholders and potential users / licensees of the DEGRICOL technology so that the different dissemination activities can be directed to the different stake holders of DEGRICOL project. That includes manufacturers of the technology, mainly the injection-moulding bioplastic products and fibre extrusion bioplastic products.

- General internet search: Preliminary web search is performed so initial approaches can be done to present the DEGRCIOL project and expected results and see the possibilities for commercial agreements.
- Individual business contacts from own networks. Both consortium RTDs, IAGs and
- SMEs identify potential candidates for the system supply chain.
- Linkedin forums. These groups put in contact different stake holders around one area of common interest. Survey and participation in these forums allow identification of potential licensees and first contacts can be established.
- Clusters like:

- Plastipolis
- TZOB
- MGH
- Zentralverband Gartenbau e. V. (ZVG) http://www.g-net.de/

Dissemination tools are briefly described and identified in a preliminary way:

- Web presence (seminars, web events, website enhancements, e-newsletter); The major platform for dissemination is the DEGRICOL webpage which was established to provide general information on the project and its activities, guidelines, check-lists, SMEs groups and researchers, information on brokerage events.
The Project website is published (released at Month 3 of the Project, in accordance to the expectations, and regularly updated) in its private and public sections, at the address http://www.degricol.org

- Release of articles in commercial magazines; Press releases have been delivered to specialized reviews and newspapers to announce the start of the project and the beginning of the research program. Subsequent Press Releases will be launched to specialized reviews and newspapers during the project execution to announce the main technological developments.

Recently Fatma GÜNDÜZ (TZOB) launched a press release in Turkey to communicate the state of the project to local newspapers.

Moreover, a scientific article has been published in two Spanish journals, titled: “Hacia una agricultura sostenible con el uso de nuevos desarrollos en plásticos biodegradables”. Both journals are specialized in plastic and environment:
F. Basurto, D. Muñoz, A. Arribas, K. Molenveld, G. Shennink, C. Thevenet. RETEMA, Revista Técnica de Medio Ambiente. Nº 182 Especial Reciclaje, 2015, pp 6-9.
F. Basurto, D. Muñoz, A. Arribas, K. Molenveld, G. Shennink, C. Thevenet. Revista de Plásticos Modernos (RPM), Vol, 109, Número 701, pp 11-14.

- Newsletters and news on partner’s websites. Madeleine Altenhein (MGH) has launched a campaign of articles and short notices that have been published periodically in MGH Newsletter and on MGH webpage. These articles are mainly addressing the MGH members (among them several horticulture producers) but the news on MGH website are also visible for everyone searching for DEGRICOL in the internet.

Public events (conferences, seminars, workshops, participation to trade fairs);

Video film for promotion of the DEGRICOL system in conferences, fairs, etc. This video will show the developed prototype and a demo simulation of how the system works. In order to use the video already during the project duration MGH will complete the video before the end of the project to show and visualize the targets of the consortium.

• Participation in congress, fairs and events: Consortium partners have participated in congress and events. These events can be used to present the ideas and results of the DEGRICOL Project. Besides, ideas for the development of DEGRICOL can be extracted from these events.

For example PLASTIPOLIS organized a conference day, on March 28th, 2013 with the group France Green Plastics, which deals with bio plastics. PLASTIPOLIS presented to French companies and searchers the different projects of FGP including DEGRICOL one. In the program a poster session was organized and people could exchange data's on the FGP projects and road map.

Besides PLASTIPOLIS was present in the K2013 fair show from the 15th until the 23rd of October 2014, with DEGRICOL flyer on their booth.

In September 2015, Inspiralia as a partner of DEGRICOL consortium, attended the ESBP2015 – 8th European Symposium on Biopolymers, hold in Rome (Italy), showing a poster named "New biodegradable plastic for a sustainable agriculture" as a participant in the posters session.

Furthermore, Plastipolis attended the Salon des Produits Innovants et Design d'Oyonnax (SPIDO Fair, 11th June 2015), showing a presentation of an overview of DEGRICOL project.

• Project brochures, posters and project presentations: A poster and a flyer describing the benefits of DEGRICOL product has been prepared by Plastipolis and MGH and can be used as dissemination tool by partners involved in the project during Conferences, workshops, seminars, etc. Moreover, SME-AGs can disseminate these flyers between their associates.
Furthermore, a presentation of the project will be prepared by the whole Consortium to use it in dissemination tasks: internal meetings with associated of SME-AIGs, visit to customers (SME), suppliers, congress, fairs, workshops, etc.
These dissemination materials are prepared under joint partner supervision for public disclosure.

# 5. Address of project public website and relevant contact details

## *5.1. Consortium Members*

| PARTNER | SHORT NAME | COUNTRY |
|---|---|---|
| PLASTIPOLIS | PLASTIPOLIS | FRANCE |
| TURKIYE ZIRAAT ODALARI BIRLIGI IKTISADI ISLETMESI | TZOB | TURKEY |
| MGH GUTES AUS HESSEN GMBH | MGH | GERMANY |
| BIOPAC (UK) LIMITED | BIOPAC | UNITED KINGDOM |
| RODENAS Y RIVERA SA | R&R | SPAIN |
| TECNOLOGIAS AVANZADAS INSPIRALIA | INSP | SPAIN |
| ASOCIACION EMPRESARIAL DE INVESTIGACION CENTRO TECNOLOGICO DEL CALZADO Y DEL PLASTICO DE LA REGION DE MURCIA | CETEC | SPAIN |
| STICHTING DIENST LANDBOUWKUNDIG ONDERZOEK | DLO-FBR | NETHERLANDS |


## *5.2. Project Contact*

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