# FINAL REPORT

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**Project acronym:** BIO4MAP

**Project title:** Transparent and high barrier biodegradable film and sheet for customized Modified Atmosphere food Packaging

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[1] 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.

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## 1.- Executive summary

The aim of BIO4MAP project is the development of **innovative high barrier fully biodegradable and recyclable**, multilayer flexible and **transparent** structure for packaging food products (fresh pasta and different types of cheese) that require customized Modified Atmosphere (MAP) by combining at least two different biodegradable thermoplastic materials, polylactic acid (PLA) and polyvinyl alcohol (PVOH), with different chemical structure and properties.

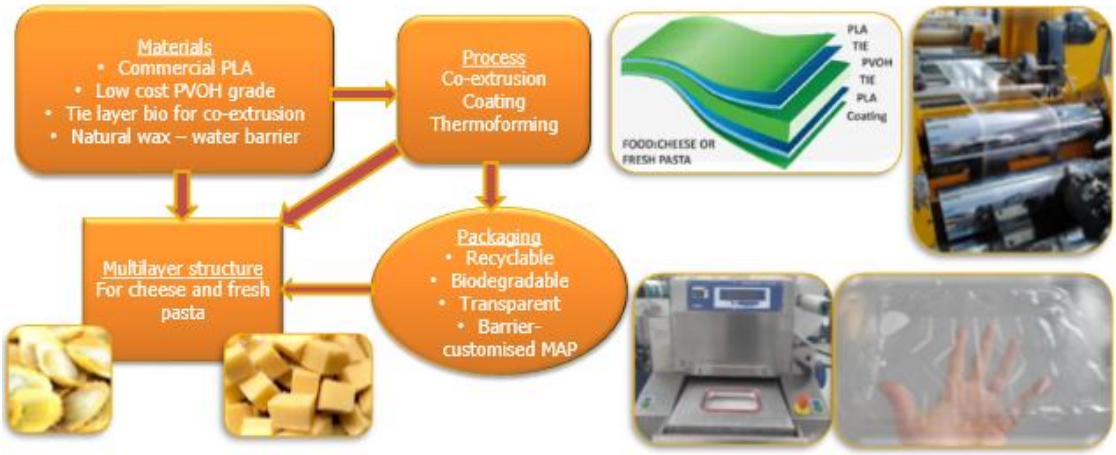
To **join both materials**, new biodegradable thermoplastic tie-layer has been developed based on the modifications of PLA or its copolymers.

To increase the **low moisture barrier** of PLA, a biodegradable coating based on natural waxes has been developed to cover the multilayer structure. Besides, it provides protection against bacteria and fungus.

The differences of permeability between traditional high barrier plastic packaging materials (combinations of polyolefins, EVOH, polyamides) and BIO4MAP's ones (PLA and PVOH), require optimization and adjustment of the current combination of gases used to obtain fully biodegradable packages that give similar shelf-life for the food products studied.

**BIO4MAP** provides environmentally friendly solutions:

1) The new packages will allow the **easy recyclability of PLA** due to the effortless separation between PVOH and the PLA (PVOH is soluble in water),
2) the new packages will be **fully compostable** in conditions according to the standard UNE-EN 13432 and
3) use of agricultural waste (leaves, greenery) as a raw material source for wax based coating production.


Materials
• Commercial PLA
• Low cost PVOH grade
• Tie layer bio for co-extrusion
• Natural wax – water barrier
Process
Co-extrusion
Coating
Thermoforming
Multilayer structure
For cheese and fresh pasta
Packaging
• Recyclable
• Biodegradable
• Transparent
• Barrier-customised MAP
PLA
TIE
PVOH
TIE
PLA
Coating
FOOD:CHEESE OR FRESH PASTA

## 2.- Summary description of the project context and the main objectives.

BIO4MAP proposal deals with the development of innovative high barrier fully biodegradable and recyclable, multilayer flexible and transparent structure for packaging food products (fresh pasta and different types of cheese) that require customized Modified Atmosphere (MAP) by combining two different biodegradable thermoplastic materials, polylactic acid (PLA) and polyvinyl alcohol (PVOH), with different chemical structure and properties.

To join both materials, **new biodegradable thermoplastic tie-layer** (for co-extrusion) has been developed based on the modifications of PLA or its copolymers.

To increase the low moisture barrier of PLA, a **biodegradable coating** based on natural waxes has been developed to cover the multilayer structure.

BIO4MAP project aims to achieve the following structure by using Co-extrusion and coating process: **PLA/tie/ PVOH/tie/ PLA/coating.**

**Main objectives:**

- To achieve processing capacity of low cost PVOH standard grades.
- Co-extrusion processing and thermoforming processes.
- To overcome PLA and PVOH incompatibility
- To evaluate the effectiveness of the developed packaging solutions for providing a competitive shelf-life by maintaining the chemical, physical and sensorial quality of the fresh pasta and cheese products.
- Natural wax use; food contact coating.
- Competitive cost.
- Take advantage of the soluble character of PVOH to have a fully recyclable package.

**Materials used:**

PLA, one of the most biodegradable polymers used nowadays, presents **excellent optical and mechanical properties** and a moderate resistance against water and fat. However, PLA does not provide suitable oxygen, moisture and other MAP gases barrier properties to extend shelf life of many food products.

On the other hand, **PVOH offers high gas barrier properties**, but its mechanical and water resistance is limited.

A synergic and smart combination of both materials can solve the limitation of each one separately, and the three main current technical drawbacks presented below have been overcome though the research proposed in BIO4MAP.

1.- **PVOH water sensibility.** PVOH has excellent barrier properties to oxygen and many other substances, because of its crystallinity and strong intermolecular forces. Because of its extreme water sensitivity and difficulty in processing, PVOH has few packaging applications. In applications where the package is sterilized or retorted the PVOH is forbidden as temperature increases the PVOH water sensibility. However in the case of

cheese or fresh pasta the food is not thermally treated after their packing, in these applications PVOH could be a suitable alternative to EVOH if the current limitations are solved (processing and improve water barrier properties given by the external layers.

*2.-* ***PVOH*** **has a limited processing window and mechanical properties.** Due to its low water resistance and special rheology, PVOH is used nowadays as a component in binder formulations and for the production of films to manufacture soluble bags. In order to have the suitable viscosity and melt strength to be used in co-extrusion process and to avoid interfacial problems between layers, **BIO4MAP project will modify PVOH by adding different types of additives to obtain a truly thermoplastic material.**

3.- **Low adhesion between PVOH and PLA**. In the current market, there are not biodegradable adhesives available which offer a suitable joint between PLA and PVOH. By developing a novel biodegradable and preferably bio-based adhesive to be used in multilayer applications, the adhesion capacity of multilayer components will be improved. **BIO4MAP will develop an adhesive based on PLA or its copolymers suitable for co-extrusion applications.**

4.- PLA and PVOH do not provide enough barrier against moisture. In BIO4MAP, **Natural wax based coating will be produced to reach the suitable barrier properties against moisture to avoid food dry** and to be sure that PVOH will maintain its gas barrier properties. Materials such as PVOH and EVOH are high hygroscopic materials and lose their barrier properties when they absorb water.

The biodegradable sheet has been covered by a natural wax based coating, to improve the water vapour permeability of the structure. Moreover, the **barrier of the developed packaging needs to be specifically adapted to the modified atmosphere required** by the different products (fresh pasta and cheese).

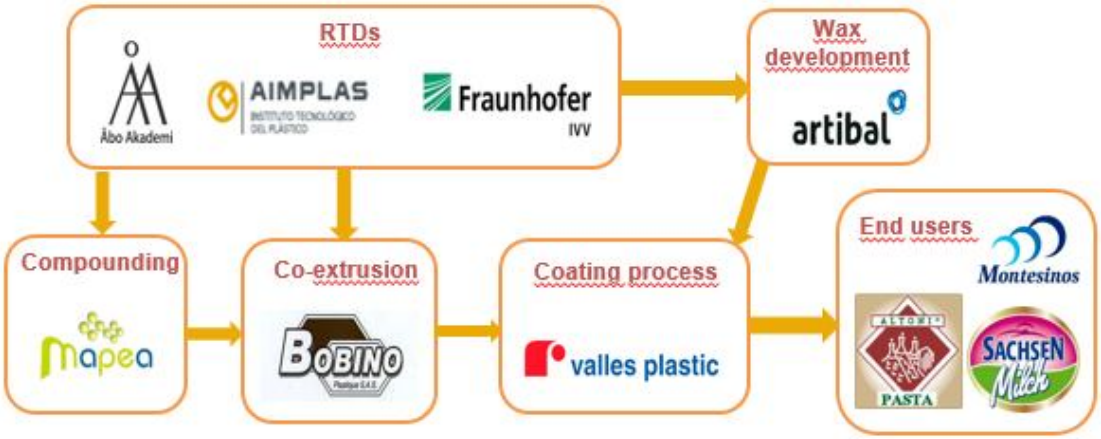
***Modified Atmosphere packaging*** (MAP) may be defined as a technique that replaces the atmospheric gases inside a package with a protective gas or mixture of gases. The gases within the package are allowed to change as the physical and biological conditions dictate. Modified atmosphere packaging is used mainly on dairy products, raw meat, raw poultry, fish products, cooked meat and fresh fruit and vegetables.

The **main goal of MAP** is significantly extending the shelf life of food products by maintaining the organoleptic properties, by minimizing the additives and preservatives' use and by delaying the growth of spoilage bacteria. MAP utilizes "minimal processing" – preserving food with the absolute least amount of damage to quality, texture, taste and nutrition.

The main destination of current multilayer MAP packages at the end of its life is landfill or incineration. The material cannot be recycled, as they are composed by non-chemical compatibles materials (mainly EVOH and polyolefins).

In **BIO4MAP** project it has obtained MAP packages based on **PLA** and **PVOH** and a natural based coating in order to provide high barrier properties. The developed packages provides the same shelf-life compared to the common petrol based material in the market. Furthermore, the suitable composition and combination of gases for each case of study (fresh pasta and cheese) will be optimized in order to maintain **their current food shelf life.**

**Consortium involved and role**



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

**Detail of the proposed project's S&T objectives.**

The aim of BIO4MAP is the development of innovative full biodegradable and recyclable, multilayer flexible and transparent structures for package food products (fresh pasta and cheese) that requires customized Modified atmosphere (MAP) by combining biodegradable polymers (PLA and PVOH) and a natural based coating.

Food preservation methods have been used by human beings since the dawn of time in order to keep foods safe and fresh for consumption for longer time. The deterioration of the fresh pasta and cheese products will immediately affect taste and appearance, due to the temperature and relative humidity.

Unsuitable packaging will shorten the shelf life of the product. As a consequence, the products case study requires a special atmosphere to retard food degradation phenomena and good gas barrier properties to preserve their organoleptic characteristics.

The suitable water vapor and gas barrier properties that will be achieved in **BIO4MAP** through combining PLA, PVOH and the natural based coating, aim to provide packaging with the optimal atmosphere composition. Afterwards, the gas atmosphere composition will be adapted to the case study food preservation needs.

Taking into account the relation between the food to be packed and the packaging system (MAP) to enlarge its shelf-life, fresh pasta and cheese products will be studied.

The general **S&T objectives** of BIO4MAP are:

- **To maintain shelf-life of** food products proposed in comparison with traditional packages by **achieving a suitable moisture and gas barrier properties** for the selected biodegradable materials.
- **The material used for the manufacture of the multilayer packaging will be at least 75% from renewable resources. These materials instead of oil-based materials will** preserve the en**vironment and the consumption o**f oil reserves, reducing also the level of atmospheric CO2 and decreasing the greenhouse effect. The project **will broaden the combination of both biodegradable materials (PLA and PVOH)** by the use of chemical modifications to change the properties of PLA and PVOH polymers and improve their compatibility in multilayer process, maintaining their good optical properties and offering a high gas barrier multilayer packaging for customized MAP. To achieve this objective, the proposed structures will have the following thickness relation:

    - **To develop a thermoplastic co-extrudable PVOH,** by adding a suitable combination of additives (different plasticizers and other aid processing additives).
    - **To increase the PLA barrier against moisture required by fresh pasta and cheese products through adding a coating to the multilayer packaging** based on food contact approval natural waxes.
    - All polymers and additives used and the chemical reaction proposed will be fulfil the FDA and European regulations to be approved for food contact applications. **Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food.**

- Be **completely biodegradable** after its life of use according to the UNE-EN 13432 standards in compostable plant conditions and be **harmless after biodegradation**, that is, no metabolites or biodegradation residuals will be formed, so there will not be toxic effects on plant or animal life.
- To avoid that 4,500 tons per year (after project finish) of multilayer films goes to landfield or order environmental unfriendly manage ways, reducing at least 15,000 t CO2 (3.4 kgCO2/Kg PETiv).

According to the requirements defined for the selected products to be studied, the objectives can be structured in the following specific items:

1. **To achieve processing capacity of low cost PVOH** standard grades by adding plasticizers to obtain a thermoplastic behaviour to be able to process in standard co-extrusion processing technologies: cast-sheet co-extrusion plus thermoforming process.

2. **To overcome PLA and PVOH incompatibility**. Through the development of a novel PLA biobased adhesive to be used in multilayer applications (co-extrusion) employing an economically and industrially feasible technology for its production. 3. To evaluate the effectiveness of the developed packaging solutions for providing a competitive **shelf-life by maintaining the chemical, physical and sensorial quality** of the fresh pasta and cheese products at the same level than existing oil-based packages do and provide a specific combination of gases for the biodegradable materials used in this project.

3. To purify and modification of **natural waxes** to obtain a **food contact approval coating** which will strength the barrier against moisture (<2 g 100 µm m-2 d-1) provided by the multilayer packaging.

4. Additionally, the wastes will be have the adequate viscosity to be processed in a standard coating equipment, thermal stability to avoid sticking problems and permit recyclability and enough flexibility to be thermoformed

5. **Competitive cost** compared to current structures listed in Table 1.3. The final cost will not be higher than 10% in comparison with packages based on non-renewable resources. Due to the combination of these materials the cost difference between the BIO4MAP sheet and EVOH and polyolefin based is lower than if single layer PET and PLA sheets are compared. This may result in a high market penetration.

6. **Take advantage of the soluble character of PVOH** to have a f**ully recyclable package** where up to a 30% of industrial scrap will be added to the virgin material in the outer layers without significant loss of mechanical properties (less than 10% reduction). Wax will be re-processed together with PLA as an additive (processing aid or demoulding capacity).

**Results obtained.**

*Films based on modified PVOH and PLA.*

The main objective has been the development of the PVOH formulations suitable to obtain the multilayer structure using extrusion technology. The low cost commercial PVOH has been modified with plasticizers by compounding to achieve a thermoplastic PVOH. This polymer is in the inner layer of the package and provides the oxygen barrier properties.

A co-rotating twin screw extruder is being used to maximize the plasticizer distribution in the matrix and to develop the new thermoplastic PVOH grade.

The compound plasticization depends on the suitable viscosity to be used in cast-sheet co-extrusion process.

The best compounds developed have been processed on the AIMPLAS pilot plant monolayer extrusion line to produce sheets (extruder + die + cooling roll + calendar). With the rheological information, the parameters for the extrusion process have been optimized.

The main parameters optimized were the temperature profile, speed of extrusion, screw design and stretch ratio. Also, the die design and roll temperature must be studied. Additionally, the mechanical and barrier properties of the sheet obtained have been measured in order to correlate them with the sheet morphology.

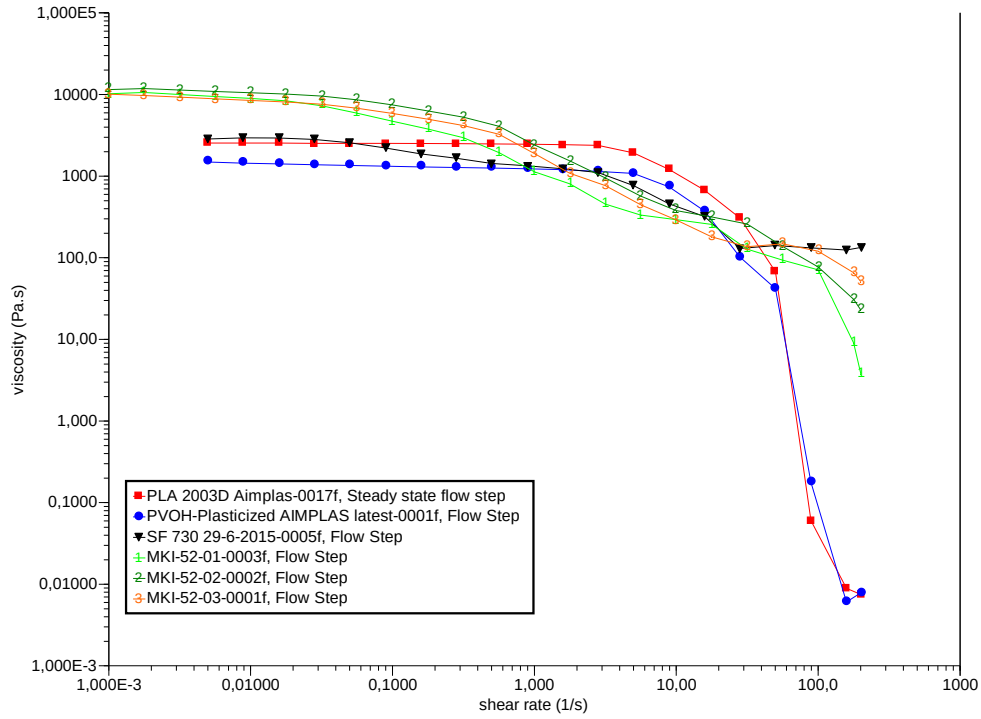
The PVOH grades developed were adapted perfectly to the cast-sheet extrusion equipment. The sheets were transparent and homogeneous and has similar mechanical properties to the commercial sheet Hi-Selon (from Nippon Goshei).

The oxygen permeability result of the PVOH sheet was below of the permeability value of a commercial barrier material as EVOH 29% ethylene (0.07 $cm^3$ 20 µm /$m^2$ day atm).

*Development of adhesive for co-extrusion process.*

The objective was to optimize and upscale the production of the tie layer compatible with PLA and PVOH to be used in co-extrusion process.

The rheology analysis give a useful information to assure that the new grade has suitable viscosity to be used in the co-extrusion equipment with the PLA and PVOH grade developed.




The initial adhesion and rheology results of the adhesives tie-layers produced were promising. Adhesion of sample developed was found to be better than commercially available non-biodegradable tie-layer.

According to the co-extrusion trials, it has found improved results with the tie layer developed. Even a high adhesion and good viscosity and processing behavior compared to previous batches.

It was decided to choose this formulation for further upscaling at MAPEA facilities.

*Development of natural wax based coatings.*

A schematic overview of the developed process is shown in the figure below:


*Results obtained:*

- Due to wax yield and availability of the raw material olive leaves were identified to be the most promising raw material for the development of a formulation ensuring water vapor barrier. However the characterization of the obtained extracts in regard with its film forming properties, hydrophobicity, viscosity and water vapor properties also need to be considered for the final decision.
- The purification of the raw materials obtained from olive or citrus plantations by means of washing and sifting is strongly recommended as the impurities negatively influence the performance of the extraction aggregates.
- The effort for the purification was significantly higher than estimated in the application phase.
- The enlargement of the surface by the utilization of grinding and cutting techniques was choosen as pre-treatment for the wax extraction; the effort was justified by an increased wax yield.
- Pilot scales for the extraction of all raw materials chosen were extracted by the developed process in order to evaluate the characteristics and especially the water vapor properties of the obtained waxes.
- As the wax yields were lower than expected, wax from olive leaves were provided for the development of a proof of concept in lab scale including formulation development, application on PLA and barrier measurements. Commercial wax was used for the pilot scale formulation development, coatings and the production of packaging samples.

- A second extraction of the extract with ethanol led to an immense improvement of the wax quality whereas the application of various absorber materials didn´t bring the desired effects.
- Depending on the extracted wax, several “washing” cycles were necessary to obtain the desired wax quality in case of olive extracts.
- No problem concerning adhesion was observed
- The particle size affects the creaming of the dispersion and big dimensions lead to unmolten particles which induce cracks and low barrier.
- The emulsifier content should be as low as possible for preserving the inherent water vapour barrier of wax, while still guaranteeing a stable dispersion. Moreover, the goal of a permeation of <2g*100µm/ (m2*d) [23°C/85%r.h.] was reached.
- Pure waxes show better water vapour barriers then blends. Although initial trials with the use of electron beam irradiation seemed to be promising, the PLA substrate became too brittle for further measurements.
- Film Forming properties are influenced by particle size and melting temperature

*Development of PLA/PVOH/PLA/coating multilayer packaging.*

The objective has been the development of suitable multilayer manufacturing processes for the production semi-rigid packaging using commercial PLA grades or the compounds and adhesives developed that fulfill the requirements of end-users applications.

The proposed multilayer manufacturing processes studied and optimized for the new compounds are:

1) **Co-extrusion cast-sheet (lid)**

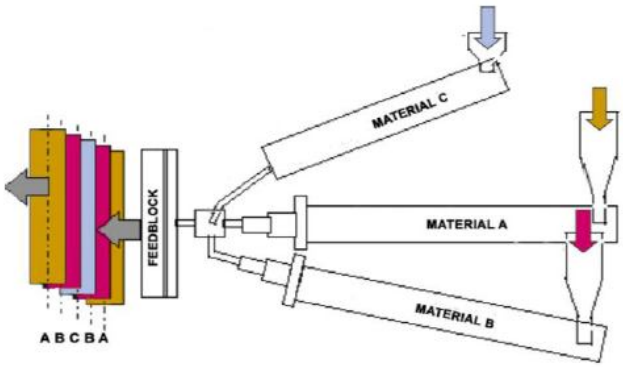
2) **Co-extrusion cast-sheet + thermoforming (tray).**

Additional **coating** substrate for improving **the water barrier properties** of the whole package (tray and lid).

**Co-extrusion cast-sheet.**

AIMPLAS has carried out different trials to optimize the co-extrusion cast-sheet process using the materials and adhesives developed and an available PLA commercial grade for cast-sheet extrusion.

A pilot plant 5 layer co-extrusion line has been used for this task.




The objective is to combine the different extrusion grade compounds developed in order to fulfill the requirements of defined tray case-studies (cheese and fresh pasta). The BOBINO's support and experience regarding to co-extrusion processes has been taken into account to evaluate the pilot plant trials.

It is proposed to obtain sheets by means of cast-sheet process to obtain the material needed to pack the food in all the case studies:

- A thicker sheet to obtain a semirigid tray using thermoforming process (to pack cheese products and fresh pasta).

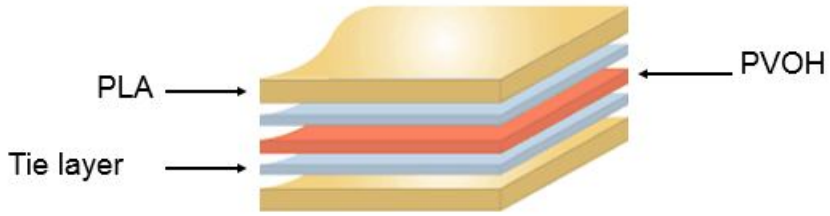
- A thinner sheet to obtain the lid to close the tray packaging, for cheese and fresh pasta.

Using the rheological data, the parameters for the extrusion process are being optimizing (at the pilot plant) for the selected compounds. During the use of this pilot-plant equipment, the following aspects of each multilayer configuration are being controlled and optimized:

- Control of processing temperatures' profile of each extruder.
- Speed in each extruder to provide an adequate residence time (right viscosity).
- The thickness of each layer according to the material's properties and extruders output to avoid problems of flow and/or interface instabilities.

Once the optimized PVOH and tie layer were developed, a co-extrusion trial was performed at pilot plant level.

The materials used and the structure obtained is shown in figure below




The figure below shows an image of the pilot plant process to obtain the multilayer structure.

A multilayer structure was obtained. The process conditions were stable during the co-extrusion process.

The total thickness was 300 and 600 microns and the thickness ratio was 8/1/2/1/8 according to the definition in Annex I to optimize the cost of the final structure. Also, a thin (70-100 microns) multilayer sheet was obtained as a lid to close the tray.

No defects were found in multilayer structure (uniform thickness along the sheet, good transparency and brightness, etc.).

**Coating process.**

To cover the sheet with the wax developed, following parameters have been considered in the wax optimization to optimise the final properties:

- Viscosity, pH, spreading capacity, drying characteristics, surface tension, mechanical strength, resistance to heat, food compatibility.

**Semi-rigid tray production at pilot plant and characterization.**

Using the multilayer sheets produced and a semi-automatic thermoforming machine, the processing window (temperature, time and pressure) of these sheets optimized over a pilot plant thermoforming mould with simple tray shape have been studied.

A pre-blowing thermoforming process has been employed in order to obtain a better thickness distribution.

The sheets obtained have been correctly thermoformed.


After that, the lid has been sealed to the tray using a thermosealing machine.


**Full package characterization.**

The new grades developed have been modifying according to the co-extrusion process feedback.

The requirement defined for the **mechanical tensile strength** value of the package developed was between 40-50 MPa, so the BIO4MAP multilayer package is suitable for the final applications.

The new development fulfil the **barrier requirements** defined: the oxygen gas transmission of the final package was 0.022 $cm^3$/(tray*day*bar) and the water vapour transmission was 1,39 g/(m2*d). This values are below the required value of 2 $cm^3$/(tray*day*bar).

The determination of the **overall migration** is done according to UNE-EN 1186-14 “Materials and articles in contact with foodstuffs-Plastics-Part 14: test method for substitute tests for overall migration from plastics intended to come into contact with fatty foodstuffs using test media iso-octane and 95% ethanol” (January 2003).

Regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food, determines the migration test conditions to be applied in each kind of sample and application.

The values of the migration was 2.2 mg/dm$^2$, below of the maximum allowed (10 mg/dm$^2$)

About the **transparency** of the final multilayer structure, when the wax coating is applied, is good enough to see clearly the food inside.

*Industrial scale up and product validation.*

**Scaling up of the PVOH' compounds production.**

PVOH with suitable viscosity for co-extrusion process has been manufactured in the AIMPLAS' facilities. AIMPLAS provided to BOBINO 100kg of material to test the inner layer at the industrial scale.

**Optimization and upscaling at MAPEA facilities**

Adhesive tie-layer was shortlisted for upscaling owning to its higher adhesion and rheological properties.

MAPEA performed further upscaling and optimization of the adhesive formulation and manufacturing process.

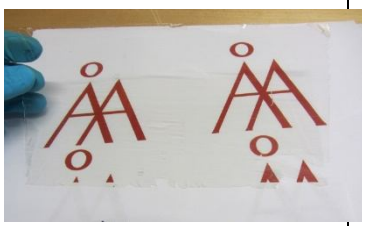
Target was to produce 60Kg batch for industrial scale co-extrusion trials at BOBINO facilities.

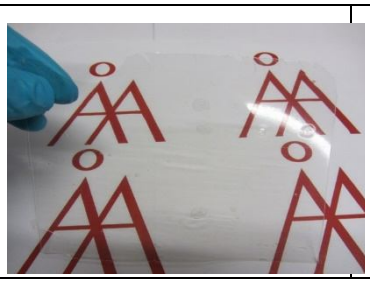
Prior to that, Åbo Akademi transferred all the knowledge and experience which were acquired during the development process to MAPEA in the form of a formal manufacturing guideline report.

MAPEA performed various production trials to replicate the attained knowledge and get comparable product obtained at pilot plant level. Manufacturing parameters such as raw material feeding, temperature profile, residence time and fed-rate were all adjusted accordingly to the equipment in house.

Åbo Akademi performed characterization of those adhesives sent by MAPEA to see the effect of adjustment and suitability of adhesive as tie-layer.

Adhesion strength and transparency of some of the tie-layers from MAPEA are compared. A gradual improvement in bland appearance, film transparency and adhesion can be seen. In table below there is a comparative between grades obtained at pilot plant and at industrial level.

| Sample ID | Granule Appearance | Film Appearance | Adhesion Rating | |
|---|---|---|---|---|
| | | | PLA/adh | PVOH/adh |
| Pilot plant grade |  |  | 4.5 | 4 |

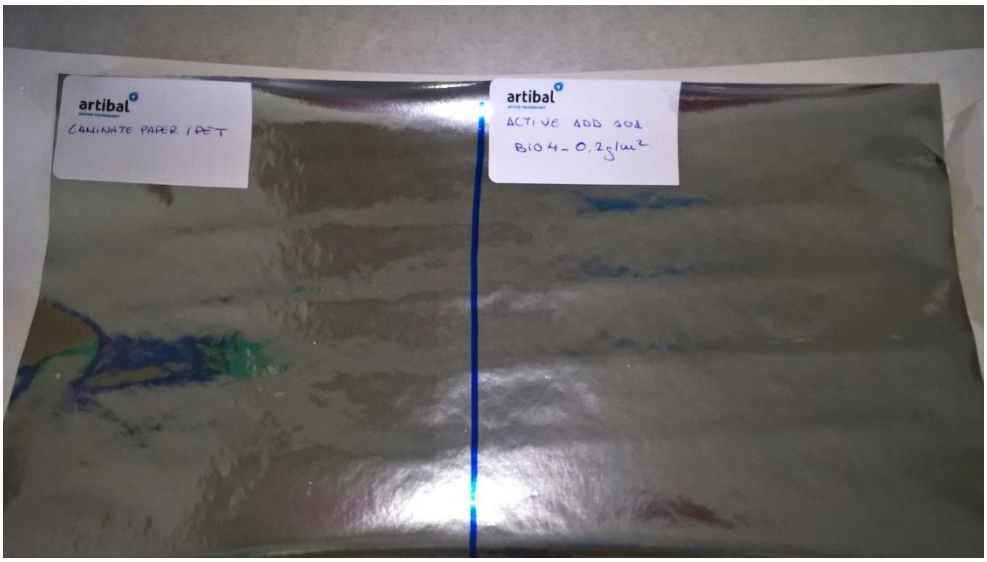
| | | | | |
|---|---|---|---|---|
| Industrial grade |  |  | 2 | 4 |

MAPEA successfully produced 60Kg of tie layer and sent it to BOBINO for co-extrusion trials.

**Scaling up of wax dispersion production at Artibal**

ARTIBAL work consisted on the manufacturing of wax at lab scale using the information provided by Fraunhofer. Figure below illustrates product appearance.


Lab sample sheets were prepared by coating a dry grammage of 0.2 g/m$^2$ onto different material. No problem was observed while working with PET, paper laminated with PET or aluminium.




As can be seen, application of the wax did not change material appearance. As for the physical properties, adhesion onto the material was not completely correct according to Artibal' standards under the TESA test (3.5/5 in Artibals own qualitative test), and there were other properties, such as thermal resistance that were not that good.

Main work during this task was the production of a semi-industrial batch of the selected wax. The process was adapted from the guidelines provided by FRAUNHOFER

There was a clear phase separation between the components of the wax formulation. This separation can be overcome by stirring the product and keeping agitation during the entire usage cycle.

Product developed was shipped to VALLES PLASTIC, printing partner for final application and evaluation.

**Scaling up co-extruded and coated sheets**

The co-extruded sheet obtained at pilot plant level has been scaled-up at industrial level in BOBINO facilities.

The process parameters obtained at pilot plant level has been optimized to obtain a multilayer structure without interfacial instabilities and encapsulation problems at industrial level.

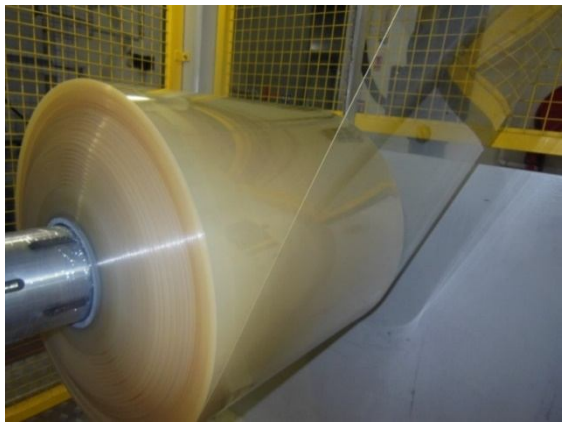
During the use of the industrial equipment, the following aspects of each multilayer configuration have been be controlled and optimized:

- To optimize processing temperatures' profiles of each extruder.
- Speed of extrusion in each extruder. This parameter offers us the adequate residence time that allows the material to flow with the right viscosity.
- The thickness of each layer obtained according to the material's properties and extruders output to avoid problems of flow and/or interface instabilities.

The thermal, mechanical resistance, thickness distribution and homogeneity have been used as control parameters.

No defects were found in multilayer structure obtained at industrial level. It has been obtained uniform thickness along the sheet, good transparency and brightness, flexibility, etc. The material did not show any interfacial defects and the process was very stable.

It was obtained several transparent film between 100 (for the lid) and 500 µm (for the tray) thickness.



It has been possible to continue with the coating trials, thermoforming, packaging and shelf-life studies using this multilayer sheet.

**Coating process**

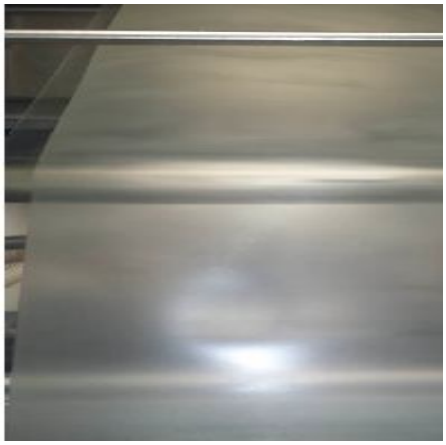
As all previous trials were performed in lab scale, pilot plant trials at Fraunhofer IVV facilities have been carried out.

The results **were extremely good, as even without any additive, the Q100 of <2g*100µm/ (m2*d) [23°C/85%r.h.] has been reached**.

The processes developed at pilot plant scale has been transferred to industrial level in ARTIBAL facilities for purpose of providing sufficient material for coating scale-up in VALLES equipment.

The yield obtained in the wax extraction from olive leaves at pilot plant level were less than the yield obtained at laboratory scale, and it was not possible to achieve the transparency and the barrier requirements. It has been decided to use commercial carnauba wax for the industrial trials.

During the coating process, the needed drying temperature of the wax was adjusted in the drying tunnel to not affect thermally to PLA. Only temperature from the upper side (wax side) was applied. The tension should be kept at a minimum to have enough time to dry the wax before winding process.

To assure that the properties of the wax applied at industrial level maintain the barrier properties of the coating obtained at pilot plant level, a permeability analysis has been done.

After the water vapour transmission rate analysis, it can be assure than the goal of the Q100 of <2g*100µm/(m2*d) has been reached.

**Scaling up thermoformed semi-rigid tray.**

The production processes of the tray at pilot plant level has been scaled up to an industrial level by packers companies using the coated material provided by VALLES. The multilayer sheet developed has been thermoformed to obtain the final trays to be used in each case study in the project. A short semi-rigid package production has been carried out to do the validation test for cheese and fresh pasta products by ALTONI-KELD, MONTESINOS and SACHSENMILCH.

The heating time were adjusted according to the thickness of the sheet. In all cases the material adapts the mould shape perfectly.


After the thermoforming process, the food was put into the tray and the lid was sealed. MAP composition was used in each case study.

*Biodegradability Evaluation, Environmental, Economic, Safety and Regulatory studies.*

**Evaluation of biodegradation of the full package in laboratory scale test.**

**The BIO4MAP package is** considered **compostable** because:

- Parameter values obtained from the **chemical analysis** of the test sample conformity with the requirement standard. The sample contains >50% of volatile solids.

  The concentration of regulated heavy metals and other toxic substances of the test sample is below than values given in standards EN 13432.

- **Biodegraded** >90% or >90% of the reference substance **(135 % biodegradation degree).**

- After 90 days in a controlled composting test, no more than 10 % of its original dry mass remains after sieving through a 2.0 mm sieve (**90.99 % disintegration degree**).

- The seedling germination rate and plant biomass of the sample compost mixtures were >90% (relative to the blank compost mixture).

**Carbon footprint.**

The results of the assessment confirmed that the **carbon footprint of the BIO4MAP packages is lower than that of conventional packages** regardless of the EoL scenario assumed, except if conventional packages are recycled at their end of life.

BIO4MAP packages performs significantly better than the conventional ones for any other end-of-life scenario in terms of climate change impact. **The total carbon footprint of BIO4MAP packages is about 29% lower than in conventional packages when the end of life is incineration** with or without energy recovery.

**The carbon footprint of the materials used in the BIO4MAP packages is 57.3% lower than in conventional packages.**

The **carbon footprint of the end-of-life stage is also lower in BIO4MAP packages** when compared to the conventional ones.

If we take into account the benefits of energy recovery, **the incineration of BIO4MAP packages has a carbon footprint 20.6% lower than their composting**.

Finally, it should also be highlighted that the **BIO4MAP packages are easily recyclable due to the effortless separation between the layers of PVOH and PLA, since PVOH is soluble in water**. This will allow to obtain recycled PLA with good quality. The recycling of the new packages was not assessed in this study because there are no

current recycling schemes for post-consumer PLA packages. However, it is hoped that this trend will change with the growth of the PLA market.

**Analysis of the new packages' recyclability.**

A study of the **re–processability** of industrial scrap or post-consume packages has been carried out in order to establish if the recycled material may be incorporated to some extent without influencing negatively the properties of the new products. PLA and PVOH separation has been carried out by means of grinding and washing process (simulating a standard recycling plant) in order to recover PLA polymer (80-90% w/w of the package), thanks to the water solubilization of the PVOH). Natural wax is water resistance, so it cannot be removed in washing process. This material can be used with PLA because acts as a plasticizer and a processing aids.

For recycling tests, the material was cut into small pieces and whashed.

Once the material was grinded and the PVOH dissolved, it has been extruded several times in order to estimate if the mechanical properties of the PLA were influenced by the processing. This give information about the reciclability of the material. The material was re-processed 3 times.

The pellets obtained during the several extrusion process cycles has been used in a hot platen press to prepare the specimen for the test analysis.

A tensile testing has been performed to all the samples obtained.

Taking into account the results obtained, there is not negative effect from the extrusion processing, so the material has not suffered degradation. Therefore, the material can be used recycled because it maintain the properties.

**Economic analysis**

In the final economic report, the cost estimation has been done in all the cases (for fresh pasta, two types of cheese), taking into account the cost of the materials used to obtain each material, processing cost by cast-film co-extrusion and coating application, and the biodegradable cost evolution.

The reference material used to make comparisons were mainly PE, PET and EVOH.

The conclusions obtained of this study revealed that producing biodegradable packages based PLA, PVOH, Tie Layer and wax-coating is competitive in price with the multilayer conventional packages for Altoni Keldermann and Montesinos, achieving an improvement in the final cost by 13% and 25%, respectively.

Related to Sachsenmilch one, no savings were found because the current package used in the evaluation is not a high barrier package.

Therefore, depending on the conventional material that has been used for the industrial partners packaging, **a cost reduction of approximately up to 25% can be possible** by the usage of Bio4MAP products.

Moreover, biodegradable market trends foresee a positive scenario for the BIO4MAP packages commercialization in 5-years time. The market updating predicts a decrease in the price of biodegradable polymers because of an increase in the global demand and production.

**This scenario predicts a promising future in the market implementation of the new developed BIO4MAP packaging.**

**Regulatory and safety issues.**

The **regulatory analysis and safety issues** studied assure that the materials used to obtain the package fulfill the regulations and has a suitable overall migration.

## 3- Description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results.

### *Market trends of biodegradable plastics*

The worldwide output of plastics in 2014 was 311 million tons[i], the plastic products increase each year (see Figure 58), and the management of plastic disposal is a problem. As a consequence of the problem caused by the management of plastic waste and the hazard conventional plastic waste in the environments, there has been an increasing interest in using alternative materials such as biodegradable plastics. These plastics have the following environmental benefits:

- Biodegradable plastics are completely and rapidly degraded in compounds which do not harm the environment. In the case of the BIO4MAP project, the raw materials used are biodegradable and compostable.
- If they are based on renewable sources, this contributes to the preservation of fossil supplies on Earth. In BIO4MAP project, higher percentaje of the final structure materials selected is PLA, which is from renewable sources.
- There is a significant energy saving since a subsequent waste management process is not required.

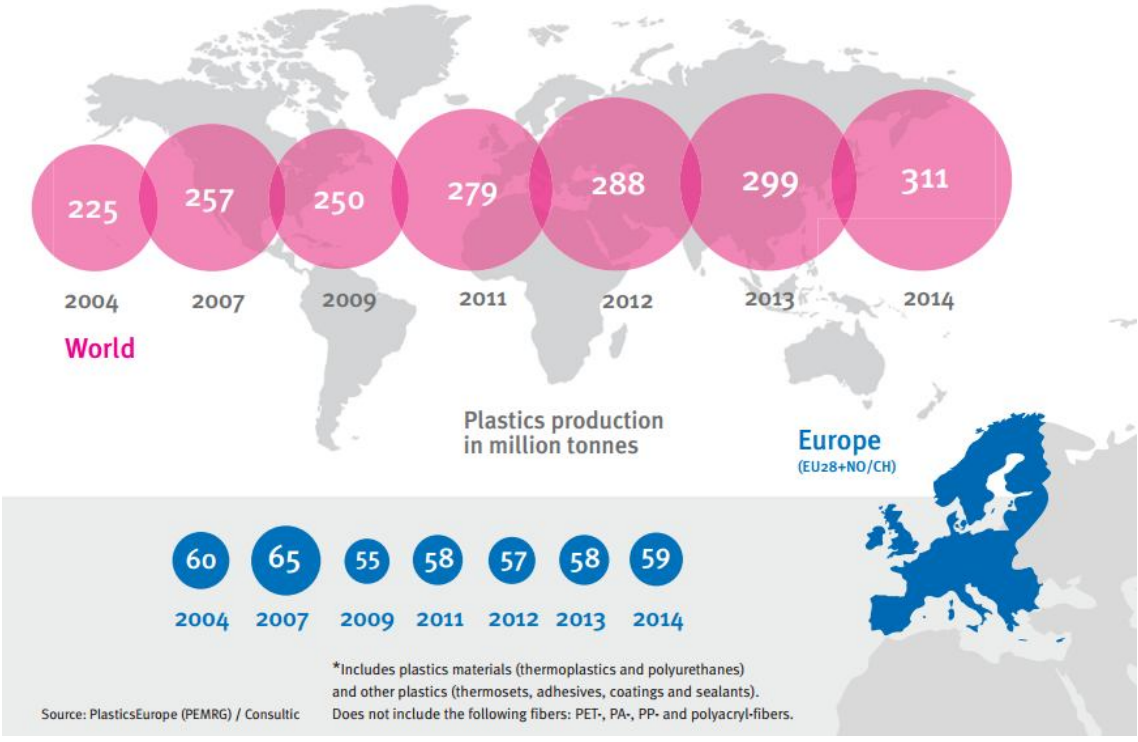



**Figure.** Global Plastic Production until 2014 (Source PlasticsEurope)

The total polymer consumption of Western Europe is about 59 million tonnes per year. According to the University of Utrecht, bioplastics could technically substitute approximately 42 million tonnes of this consumption. Technically, biobased plastics could potentially be a substitute for around 85 percent of polymers[ii]. Nevertheless, there is simply not yet enough volume produced to make this a short or medium term possibility.

According to European Bioplastics, the total capacity of bioplastics (compostable and non-compostable) by the end of 2015 have been more than 2.000 kTon. Although bioplastics constitute at present less than 1% of the total market of plastics, they present a high growth potential. The expectative even shows that global demand can increase up to almost **8 million tons in 2019** (see Figure 2).

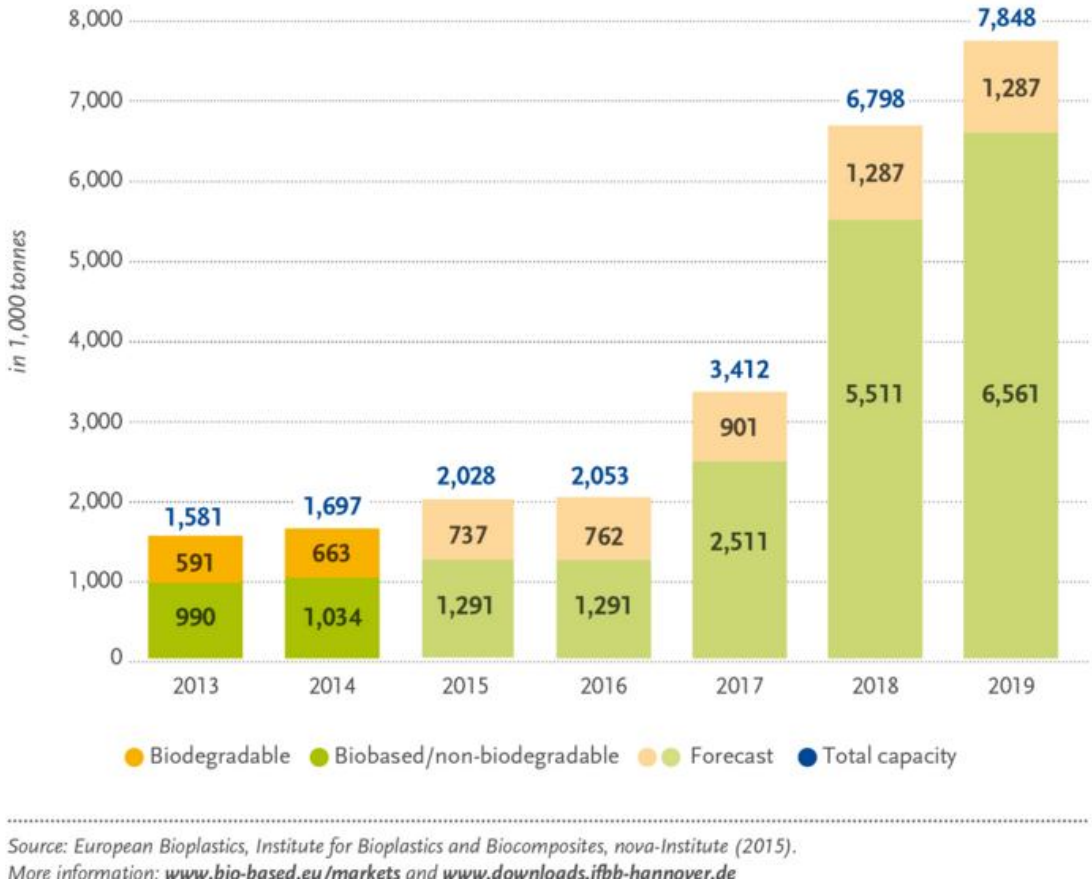



**Figure 1.** Global production capacities of bioplastics until 2018. Source: European Bioplastics[iii]

The forecast predicts the bioplastics industry is going to unfold an immense economic potential over the coming decades. By 2025, production capacities of bioplastics within the EU could grow to up to 5.7 million tonnes per year, 10% of the European plastics production.

North America, Europe and Asia had over 87% of global production of bioplastics in 2014. Figure 3 represents these data.

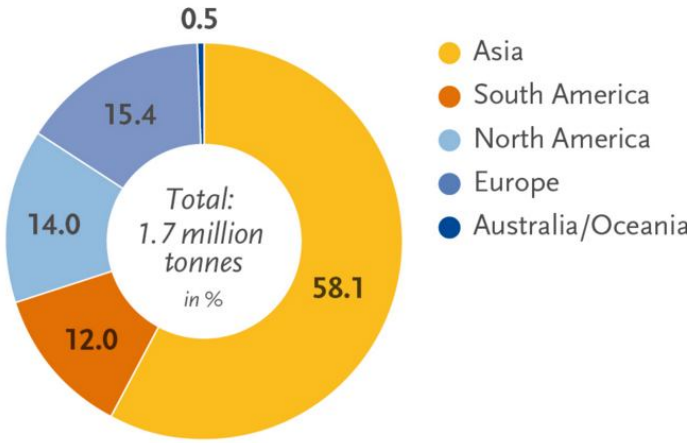



**Figure 2**. Global production of bioplastics in 2014 by region. Source: European Bioplastics[iv]

The objective of the BIO4MAP project is to obtain a high barrier packaging for fresh pasta and two types of cheese. The materials used in the project were mainly polylactic acid (PLA) and PVOH.

Only 40% of the global production of bioplastics is biodegradable materials and PLA is over 12% of these materials as Figure 4 shows.

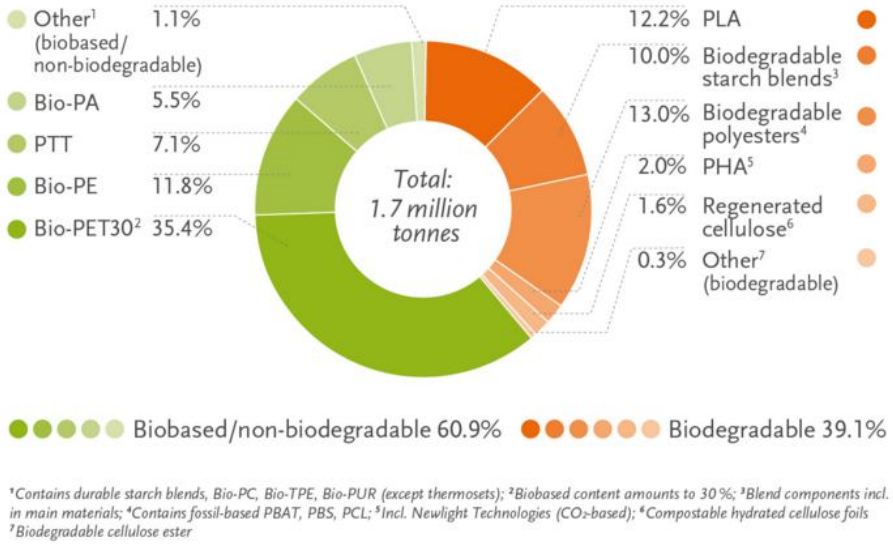



**Figure 3**. Global production of bioplastics in 2014 by material. Source: European Bioplastics[v].

### *Biodegradable plastics in packaging*

Packaging has achieved an important presence on people´s daily life with a constant growth during the last years, providing a share with a market of 38 billion Euros in Europe[vi]. Consumption per capita in EU-12 rose by 9.4 % between 2005 and 2011 with an average annual increase of 1.6 €[vii].

The package material is experiencing a process of environmental change due to the use of bioplastics in packaging sector where over 65% of the Global production capacities of bioplastics in 2014 were consumed in flexible and rigid packaging. Figure 5 represents these data.

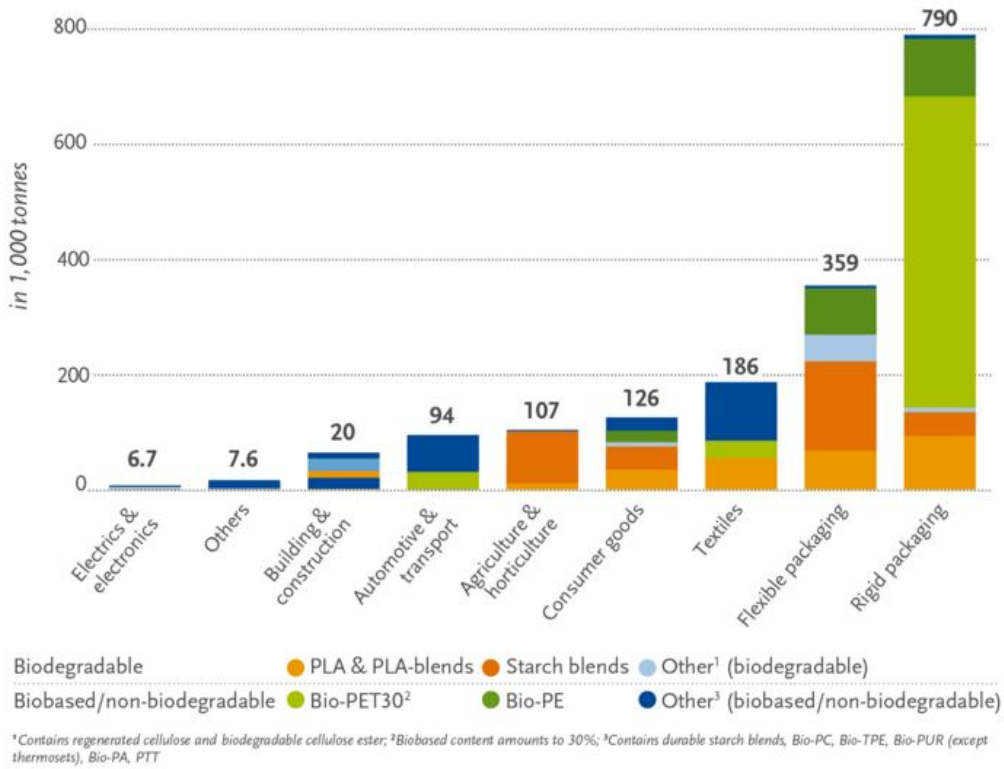



**Figure 4.** Global production of bioplastics in 2014 by market segment. Source: European Bioplastics[viii]

In 2014, global production capacities of bioplastics amounted to about 1.7 million tonnes with almost 70 percent of the volume destined for the packaging market, the biggest market segment within the bioplastics industry.

Regarding to the food-service packaging, the market volume in Germany, in the catering sector, including among others plastic silverware and crockery, paper and cups, amounts to roughly 3.5 billion Euros. In the last ten years, this market has grown on average by seven percent each year. As a result, there is a broad spectrum of bioplastics products available for the food and catering segment.

The benefits provided by **BIO4MAP** to the participant SMEs in order to increase their competitiveness are:

- ***Semi-rigid packaging manufacturers***

  BOBINO will broad their range of products by offering new products not available in the market full biodegradable and recyclable, multilayer and transparent structures for package food product that require customized MAP. This will increase their volume of business, since it is expected that the new biodegradable package will have a higher acceptance by customers (low environmental impact, provide an optimal food shelf-life and health), due to its performance is competitive compared to the existing packages made-of oil based polymers. Besides, the new packages are a higher added value product that will allow European manufacturers to differentiate them from far-east competitors.

- ***Coating manufacturer***

VALLES will offer a broader range of products as a result of the biodegradable water vapour barrier coating developed. The developed coating will be employed on sheets for semi-rigid packages that need to reinforce their barrier against moisture. Besides, the new packages also are a higher added value product that will allow European manufacturers to differentiate them from far-east competitors. Global consumption volume of paints and coatings is expected to amount to approx. 48[ix] million tonnes in 2019 and to thus continue to accelerate growth in comparison to the previous eight years.

- ***Natural wax coating producers***

ARTIBAL will widen their market penetration through achieving the knowledge to purify and extract the wax from natural sources to be used afterwards as a raw material for producing the biodegradable water vapour barrier coating based on natural waxes.

- ***Compounders and Adhesive modifiers***

MAPEA will increase their volume of business because a new market will be created (adhesives biodegradables production is currently slightly introduced on the market). Moreover, they will gain expertise in optimizing processes for obtaining biodegradable adhesives.

- ***Cheese and fresh pasta producers***

SACHSENMILCH, MONTESINOS and ALTONI KELDERMAN will benefit from the biodegradability and customized MAP of the new sustainable high water barrier packaging which will permit to provide high quality, health and shelf-life of the food to be packed and also to offer to the packaging an environmental friendly end-life.

The customized MAP increase the knowledge in obtaining the suitable combination of gases for biodegradable (PLA and PVOH) packages. They can obtain a cost reduction by reducing of amount of scrap production. The development of the biodegradable packages with customized MAP represents in fact an innovation from which the end-users can benefit by increasing their expertise and by offering higher added value products.

**Dissemination actions.**

Dissemination activities done during the whole project are presented at the table below:

## Project Dissemination Activities

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 1 | Web sites/Applications | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | project website | 01/12/2013 | website | Scientific community (higher education, Research) - Industry |
| 2 | Web sites/Applications | FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V | Information about project in FhG website | 01/01/2014 | website | Scientific community (higher education, Research) - Industry |
| 3 | Web sites/Applications | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | Information about project in AIMPLAS website | 01/01/2014 | website | Scientific community (higher education, Research) - Industry |
| 4 | Web sites/Applications | ALTONI-KELDERMAN NV | Project information available at the University website (www.abo.fi) | 01/01/2014 | website | Scientific community (higher education, Research) - Industry |
| 5 | Web sites/Applications | VALLES PLASTIC FILM, S.L. | Information about project in VALLES website | 01/03/2014 | website | Industry |
| 6 | Interviews | ABO AKADEMI | Snart kan osten packas i ekoplast | 01/02/2014 | Radio Vega | Civil society |
| 7 | Oral presentation to a scientific event | ABO AKADEMI | Research activities at Åbo Akademi University | 01/02/2014 | Germany | Scientific community (higher education, Research) |
| 8 | Articles published in the popular press | ABO AKADEMI | Interview in the printed engineering magazine Tekniikka & Talous | 01/03/2014 | Tekniikka&Talous | Scientific community (higher education, Research) |
| 9 | Oral presentation to a scientific event | ASOCIACION DE INVESTIGACION DE MATERIALES | Information about BIO4MAP at the Biodegradables Seminar held in Valencia (Spain) | 03/03/2014 | Valencia, Spain | Scientific community (higher |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| | | PLASTICOS Y CONEXAS - AIMPLAS | | | | education, Research) - Industry |
| 10 | Press releases | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | Project information at different websites: Interempresas, Special Chem, Packaging Europe, Packaging Gateway, EPPM (http://www.eppm.com/industry-news/aimplas/) | 05/05/2014 | website | Industry |
| 11 | Press releases | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | Information about project at Films and sheet extrusion publication (www.fi lmandsheet.com) | 05/07/2014 | magazine Film and sheet extrusion | Industry |
| 12 | Flyers | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | Leaflet handled during Equiplast Fair | 20/09/2014 | Barcelona (Spain) | Scientific community (higher education, Research) - Industry |
| 13 | Press releases | ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS - AIMPLAS | Information about BIO4MAP at Food packages (http://www.foodpackages.net/index.php?ID=3063) | 05/10/2014 | website | Industry |
| 14 | Oral presentation to a wider public | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | slide 14 13 - Customized solutions in bioplastics - AIMPLAS | 13/03/2014 | - | Industry |
| 15 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Aimplas-crea-envases-biodegradables | 02/05/2014 | www.aimplas.es_blog_aimplas- - | Industry |
| 16 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS crea envases biodegradables y reciclables para quesos y pasta fresca | 02/05/2014 | http://www.aimplas.es/blog/aimplas-crea-envases-biodegradables-y-reciclables-para-quesos-y-pasta-fre | Industry |
| 17 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS develops biodegradable and recyclable packages for cheeses and fresh pasta | 02/05/2014 | Press | Industry |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 18 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Aimplas crea envases biodegradables y reciclables para quesos y | 05/05/2014 | eMagazine Producción alimentaria | Industry |
| 19 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Recyclable plastics developed for fresh food packaging - EPPM | 09/05/2014 | http://www.eppm.com/industry-news/aimplas/ | Industry |
| 20 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS with BIO4MAP to develop Transparent, Biodegradable & Recyclable Package for Fresh Food | 12/05/2014 | http://www.specialchem.com/ | Industry |
| 21 | Oral presentation to a scientific event | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | SOLUCIONES A MEDIDA EN BIOPLÁSTICOS PARA ENVASES | 05/11/2014 | "TRADEFAIR: EMPACK2014 | Industry |
| 22 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Materiales biodegradables en envases obtenidos por extrusión soplado | 28/11/2014 | www.interempresas.net | Industry |
| 23 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Envases biodegradables para productos | 02/03/2015 | "interempresas.net | Industry |
| 24 | Oral presentation to a scientific event | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS participa en HISPACK con innovaciones en envases activos, biodegradables y reciclado | 30/03/2015 | 21/04/2015 tradefair HISPACK , Madrid | Industry |
| 25 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Aimplas presentará sus últimos proyectos en Hispack | 09/04/2015 | Alimarket-Envase (Noticias) | Industry - Civil society |
| 26 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Aimplas acudirá a Hispack | 09/04/2015 | Envaspres | Scientific community (higher education, Research) |
| 27 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS anuncia su presencia en Hispack 2015 | 10/04/2015 | Mundoplast -Ferias | Industry |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 28 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS completa su presencia en Hispack con tres ponencias y con la presentación de un nuevo envase | 14/04/2015 | Platicos modernos magazine | Industry |
| 29 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Hispack acogerá la innovación en envases de plástico desarrolladas por Aimplas | 14/04/2015 | http://www.automaticaeinstrumentacion.com | Industry |
| 30 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | PROYECTO EUROPEO BIO4MAP | 15/04/2015 | http://www.fabricantes-maquinaria-industrial.es/ | Industry |
| 31 | Exhibitions | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "BIO4MAP Project | 21/04/2015 | 21/04/2015 tradefair HISPACK , Madrid | Industry |
| 32 | Flyers | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "BIO4MAP Project | 21/04/2015 | 21/04/2015 tradefair HISPACK , Madrid | Industry |
| 33 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS presenta sus innovaciones en envase sostenible en EMPACK OPORTO 2015 | 30/07/2015 | AIMPLAS WEBSITE | Industry |
| 34 | Oral presentation to a scientific event | FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. | Entwicklung einer Wachs-basierten Wasserdampfbarrierebeschichtung für MAP-Verpackungen | 01/09/2015 | Freising | Scientific community (higher education, Research) |
| 35 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS, en EMPACK Portugal | 21/09/2015 | Mundoplast website | Industry |
| 36 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Aimplas presentará sus innovaciones en Empack Oporto 2015 | 21/09/2015 | Envaspres | Industry |
| 37 | Flyers | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Bio4map at EMPACK Oporto tradefair | 24/09/2015 | EMPACK OPORTO | Industry |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 38 | Oral presentation to a scientific event | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Bio4map at EMPACK Oporto tradefair | 24/09/2015 | EMPACK OPORTO | Scientific community (higher education, Research) |
| 39 | Flyers | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Transparent and high barrier biodegradable film and sheet | 07/10/2015 | "Conama Local_Malaga | Industry |
| 40 | Exhibitions | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "Transparent and high barrier biodegradable film and sheet | 07/10/2015 | "Conama Local_Malaga | Scientific community (higher education, Research) |
| 41 | Exhibitions | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "Transparent and high barrier biodegradable film and sheet | 07/10/2015 | "Conama Local_Malaga | Scientific community (higher education, Research) |
| 42 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | MADE FROM PLASTIC reunirá en Valencia las últimas innovaciones y tendencias en envase plástico | 14/10/2015 | AIMPLAS WEBSITE | Industry |
| 43 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | En las actividades paralelas, habrá jornadas técnicas, sesiones profesionales y una exposiciónMade from Plastic reunirá en Valencia las últimas innovaciones y tendencias en envase plástico | 15/10/2015 | Interempresas.net | Industry |
| 44 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | El salón Made From Plastic, la semana que viene en Valencia | 15/10/2015 | madefromplastic.com | Industry |
| 45 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Made from Plastic reunirá en Valencia las últimas innovaciones y tendencias en envase plástico | 16/10/2015 | Plast 21 noticias | Industry |
| 46 | Flyers | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "Lámina y film transparente, barrera y biodegradable para envase alimentario con MAP a medida | 20/10/2015 | Made form Plasstic, Trade Fair Valencia | Industry |
| 47 | Oral presentation to a scientific event | AIMPLAS - ASOCIACION DE INVESTIGACION DE | "Lámina y film transparente, barrera y biodegradable para envase alimentario con MAP a medida | 20/10/2015 | Made from Plasstic, Trade Fair Valencia | Industry |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| | | MATERIALES PLASTICOS Y CONEXAS | | | | |
| 48 | Organisation of Workshops | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "Transparent and high barrier biodegradable film and sheet for | 19/11/2015 | Empack Madrid | Industry |
| 49 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Innovaciones sostenibles en envases de plástico | 18/01/2016 | website | Industry |
| 50 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Sustainability Innovations in Plastic Packaging | 29/03/2016 | website | Industry |
| 51 | Videos | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "El vídeo del Proyecto europeo BIO4MAP ya está disponible en YouTube. Con su visualización podéis tener un mejor conocimiento de su desarrollo. | 29/03/2016 | https://www.facebook.com/aimplas/posts/1256211751072953 | Civil society |
| 52 | Web sites/Applications | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "El vídeo del Proyecto europeo BIO4MAP ya está disponible en YouTube. Con su visualización podéis tener un mejor conocimiento de su desarrollo. | 29/03/2016 | https://www.facebook.com/aimplas/posts/1256211751072953 | Civil society |
| 53 | Oral presentation to a wider public | FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. | Stabilität von Wachsdispersionen | 01/04/2016 | Freising | Scientific community (higher education, Research) |
| 54 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Development of biodegradable and recyclable package with barrier properties for food application | 15/10/2016 | Packaging Europe | Industry |
| 55 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS develops biodegradable and recyclable packages for cheeses and fresh pasta | 01/01/2015 | ECP4 | Industry |
| 56 | Oral presentation to a wider public | ABO AKADEMI | A Quest for Polymeric Materials for... | 01/01/2015 | Winter school FUNMAT II - Turku | Scientific community (higher education, Research) |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 57 | Videos | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | bio4map video | 01/01/2016 | - | Industry |
| 58 | Articles published in the popular press | ABO AKADEMI | I BIOPLAST- FÖR BÄTTRE FRAMTID (Trasnslation: Bioplastics- For better future) | 01/01/2016 | Inblick (Magazine) | Civil society |
| 59 | Oral presentation to a scientific event | ABO AKADEMI | Plastic Additives | 01/05/2016 | University of Turku | Industry |
| 60 | Flyers | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | Envases biodegradables para productos queseros y pasta fresca | 01/08/2015 | - | Industry |
| 61 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | 16-08 Film & Sheet extrusion press release a preparar | 01/08/2016 | 16-08 Film & Sheet extrusion press release a preparar | Industry |
| 62 | Exhibitions | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | AIMPLAS AT EQUIPLAST | 01/09/2014 | Equiplast, International Plastics and Rubber Event | Industry |
| 63 | Oral presentation to a scientific event | ABO AKADEMI | PLASTIC PACKAGING | 01/10/2015 | Helsinki Exhibition Centre | Industry |
| 64 | Oral presentation to a wider public | ABO AKADEMI | Green food packaging technologies based on modified biopolymers | 01/11/2015 | Empack 2015 - Madrid | Industry |
| 65 | Oral presentation to a scientific event | FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. | Utilization of natural wax based coatings for plastic laminates | 01/12/2014 | Freising | Scientific community (higher education, Research) |
| 66 | Oral presentation to a scientific event | FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. | Lecture in University Kempten | 01/12/2015 | Kempten | Scientific community (higher education, Research) |
| 67 | Press releases | AIMPLAS - ASOCIACION DE INVESTIGACION DE MATERIALES PLASTICOS Y CONEXAS | "Members of the Bio4Map project have developed a | 01/07/2013 | "Film and Sheet Extrusion magazine, | Industry |
| 68 | Web sites/Applications | ALTONI-KELDERMAN NV | Company website | 02/12/2013 | Website | Industry |

| Nº | Type of activities | Main leader | Title | Date | Place | Type of audience |
|---|---|---|---|---|---|---|
| 69 | Flyers | ALTONI-KELDERMAN NV | Industry Fairs | 02/12/2013 | Industry fairs | Industry |

[i] Plastics-The Facts 2015. An analysis of European plastic production, demand and waste data. PlasticsEurope (PEMRG) / Consultic. file:///C:/Users/pdiego/Downloads/PLASTICS_THE_FACTS_2015_FINAL_30pages_14122015.pdf

[ii] http://en.european-bioplastics.org/market/market-development/potential

[iii] www.bio-based.eu/markets and http://www.european-bioplastics.org/market/

[iv] www.bio-based.eu/markets and http://www.european-bioplastics.org/market/

[v] www.bio-based.eu/markets and http://www.european-bioplastics.org/bioplastics/materials/

[vi] Capital IQ – European Plastic packaging, Spring 2012 (Mergers Alliance)

[vii] EUROPEN Packaging and Packaging Waste Statistics: 1998 – 2011.

[viii] www.bio-based.eu/markets and http://www.european-bioplastics.org/market/applications-sectors/

[ix] http://www.european-coatings.com/Markets-Companies/Coatings-Market