Bio & Smart Sustainable packaging

NATURKLIMA

Dr. Amaya Igartua| Tekniker | 21/11/2023

Contact: amaya.Igartua@tekniker.es

Tekniker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

AMi2030 ADVANCED MATERIALS INITIATIVE

IRISS

EUMAT

BBI JU

BIOSMART
BIOMATERIALS FOR SMART FOOD PACKAGING

TEKNIKER Introduction

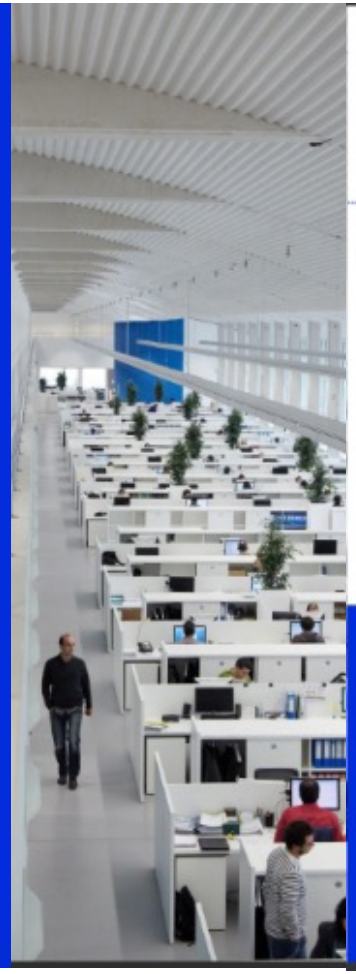
Tekniker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

WHO WE ARE

R&D Centre
(not-for-profit Private Foundation) |
Applied research spanning 42 years

Our mission is to deliver growth and wellbeing to society at large via R&D&I and to further the competitiveness of the business fabric in a sustainable manner

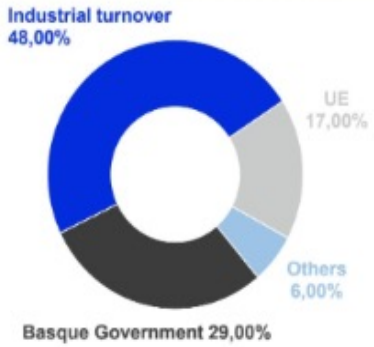
Specialised in **Manufacturing**



TEKNIKER IN FIGURES

TOTAL REVENUE TEKNIKER
25.6 M€

PEOPLE TEKNIKER
270



37% Women
63% Men

PhD resources
58 doctors
27 doctoral students

81% university degrees

DATA 2022

TOTAL REVENUES **TEKNIKER + INVESTED COMPANIES**
48.1 M€

PEOPLE **TEKNIKER + INVESTED COMPANIES**
366

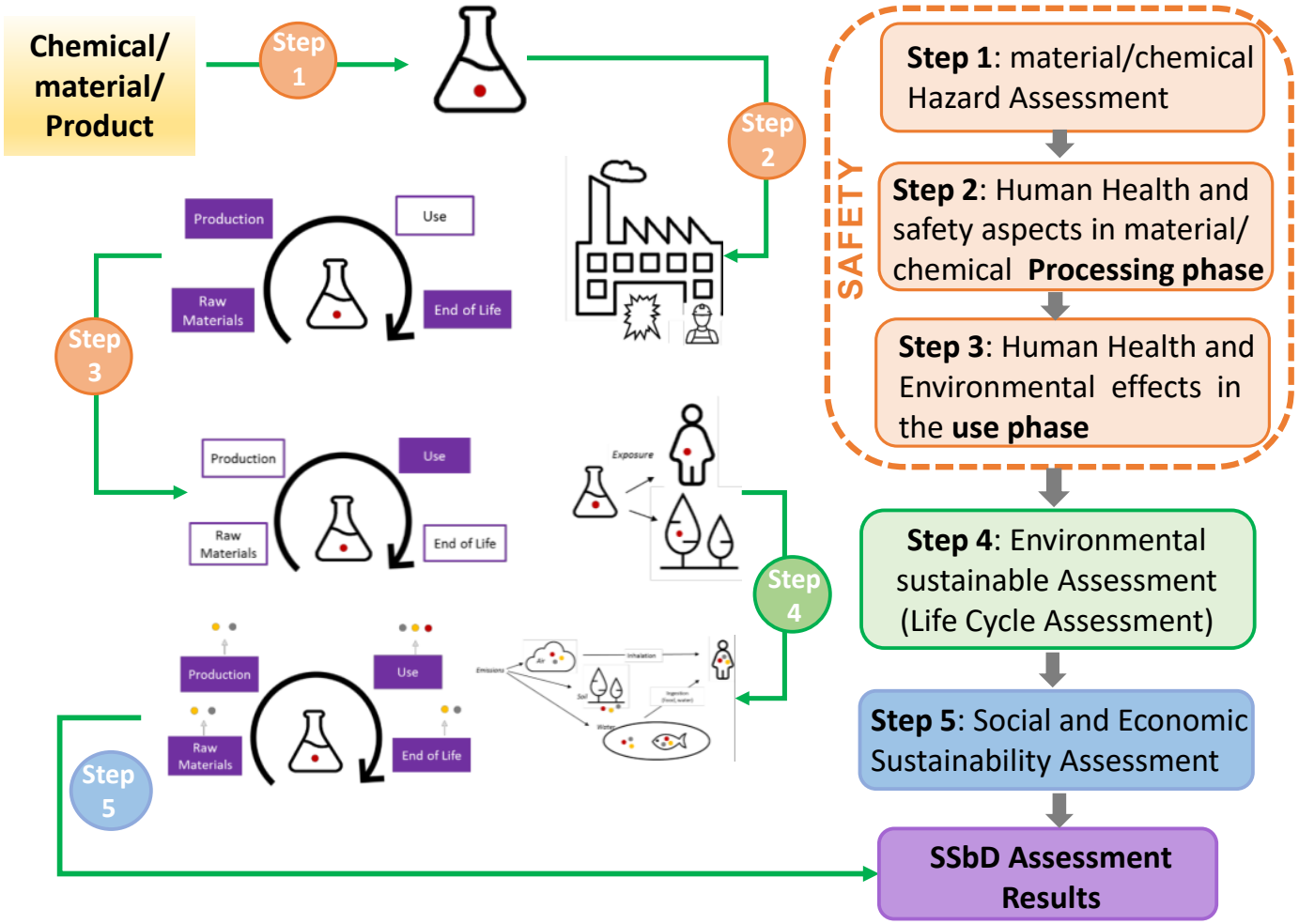
CURRENT PORTFOLIO OF SHAREHOLDINGS IN COMPANIES

ATTEN2 · masermec · GMTK · GOIALDE HIGH SPEED · H2GREEM · i-TRIBOMAT

TOTAL REVENUES INVESTED COMPANIES
22.5 M€

PEOPLE INVESTED COMPANIES
96

SSbD JRC proposed Framework [1]



[1] Caldeira et al, Safe and sustainable by design chemicals and materials - **Framework for the definition of criteria and evaluation procedure for chemicals and materials**, 2022, DOI 10.2760/487955 (online)

Bio-based smart packaging for enhanced preservation of food quality

BBI JU contribution: €3,6 million

Duration: May 2017 – December 2021

Feedstock: Sugar, Corn, Polylactic acid, nanoclays

The main goal of **BiOSMART project** is to develop **active and smart** biobased and/or **compostable packages** to meet the needs of both fresh and pre-treated food applications.

To address **future packaging demands** will need to enable light-weighting, **reduced food residues,** easier food monitoring and **longer shelf life,** simplifying waste handling, all without a price premium.

BIOSMART encompasses an approach for **integrating bioactive materials, barrier coatings and sensors** to enlarge food shelf life.

BIOSMART
BIOMATERIALS FOR SMART FOOD PACKAGING

Bio-based smart packaging for enhanced preservation of food quality

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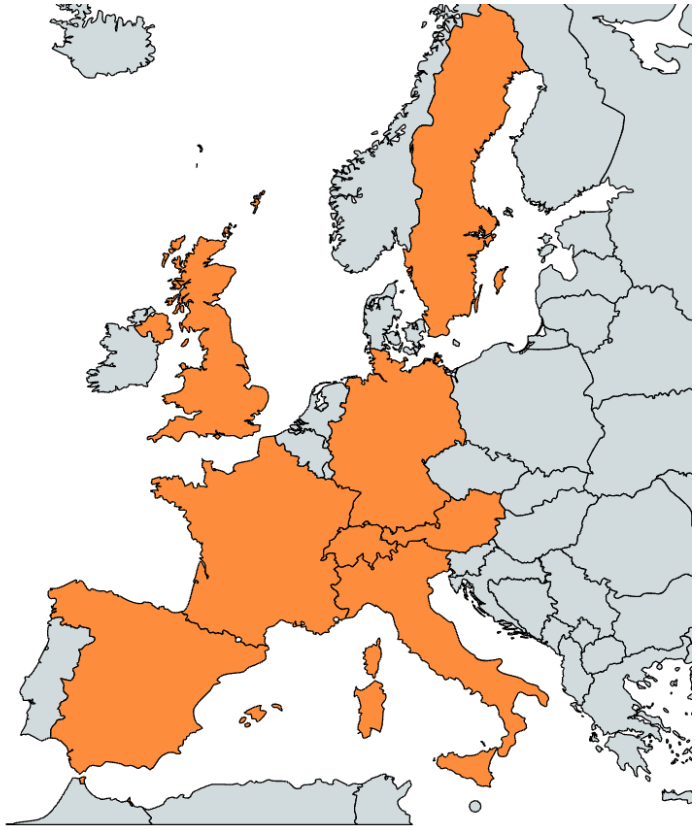
Project lead: Tekniker (Spain)

BBI JU contribution: € 3,610,866

Project Website: www.biosmart-project.eu

Duration: 01.05.2017 – 31.12.2021

- **3 UNIs**
- **3 RTOs**
- **3 SMEs**
- **2 Large Companies**



Tekniker · RISE · TECSENSE unique solutions in sensor technology · Université de Lille · University of Reading · Lipofabrik · HEIA-FR HTA-FR · ITENE · WIPAK · GEA engineering for a better world · propa group

Context and Objectives

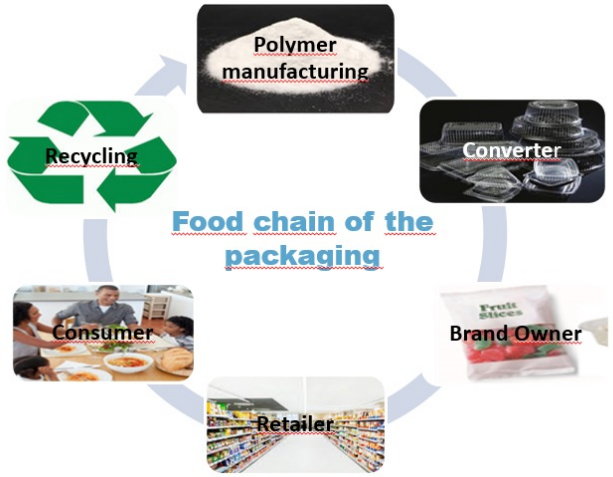
- **The Context**

- In Europe, **88 Millions Tons of food are wasted** each year, equivalent to the 20 % of the food produced in Europe.
- Waste food is sent to the weir, degrading the soil with a cost of 150M€, representing **6% of Green house emissions.**

Food lost along the value chain

- **The Objectives**

- the development of **bio-based food packaging** that **can monitor and extend shelf-life,** while being **compostable,** biodegradable **or recyclable** and friendly for the environment.
- The project has been built with the **collaboration of the complete value chain** through their participation in the Advisory Board, involving the resin manufacturer (Natureworks), the Brand Owner (Unilever) and the Retail (Eroski).



BIOSMART
BIOMATERIALS FOR SMART FOOD PACKAGING

Technical Approach

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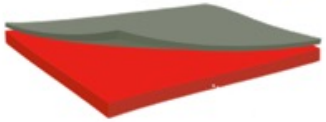
Tekniker · ITENE RESEARCH CENTER · University of Reading · TECSENSE unique solutions in sensor technology · Université de Lille 1 SCIENCES ET TECHNOLOGIES · propa group · RISE · Lipofabrik · HEIA-FR HTA-FR · WIPAK · GEA

Sensors O_2, CO_2 and volatile amines

Reinforced mechanical properties

Antimicrobial properties

Barrier coatings Oxygen, water, UV



Thermal regulation

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BIOMATERIALS FOR SMART FOOD PACKAGING

Achievements:

What	How	Who
The food shelf-life monitoring	The development of oxygen, CO_2 and amine sensors to monitor internal gas evolution in modified atmosphere food packaging.	TECSENSE unique solutions in sensor technology; GEA engineering for a better world
The extension of food self-life	The development of biobased lipopeptides in combination with peptides have antifungal and antimicrobial properties. The lipopeptides can be linked to the surface using cold atmospheric plasma.	Université de Lille; Lipofabrik; University of Reading; HEIA-FR HTA-FR
The biobased polymers	The development food approved compostable Polylactic Nanocomposites to improve mechanical and barrier properties. Development of biobased poly(ester-amide) copolymers (PEA).	ITENE; HEIA-FR HTA-FR
The functionalities	The development and characterization of superhydrophobic, anti-adherent and the encapsulation of biobased phase change materials to keep temperature longer to preserve food self-life.	Tekniker MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE; Université de Lille

BIOSMART
BIOMATERIALS FOR SMART FOOD PACKAGING

Achievements:

Tekniker
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

What	How	Who
The barrier layers	The development of food protective barrier coatings (oxygen, water and ultraviolet).	ITENE, Tekniker
The packaging	The development of smart biobased plastic MAP packaging, paper biobased laminate and a new concept of smart packaging ready for recycling.	ITENE, WIPAK, GEA engineering for a better world, propa group
The Web Application tool	The development of an **Application** for selection of biobased materials, performance and functionality for commercial needs of the packaging.	HEIA-FR HTA-FR

More details: www.biosmart-project.eu

The materials safety assesment
Lipopeptides

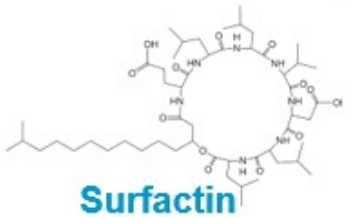
Biosmart actives lipopeptides and characterization

Biological activities

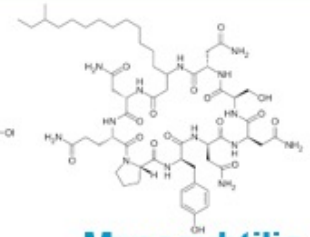
Antifungal

Antimicrobial

Antiradical and antioxidant
DPPH scavenging activity and inhibition of superoxide anion, hydrogen peroxide and hydroxyl radical



Surfactin



Mycosubtilin

Cytotoxicity
kidney (Vero-SF) and gut (Caco-2 cells)

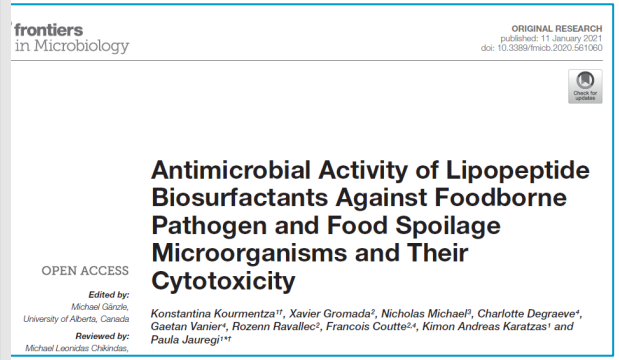
Toxicity

***In vivo* study**
Repeated dose 90-day oral toxicity study in rodents.
(OECD: Test No. 408)

Bacterial reverse mutation test/AMES test
(OECD: Test No. 471)

Mutation tests using the thymidine kinase gene
(OECD: Test No. 490)

Chromosomal aberration assay (OECD: Test No. 473)



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University of Alberta, Canada

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Antimicrobial Activity of Lipopeptide Biosurfactants Against Foodborne Pathogen and Food Spoilage Microorganisms and Their Cytotoxicity

Konstantina Kourmentza[†], Xavier Gromada[2], Nicholas Michael[3], Charlotte Degraeve[4], Gaetan Vanier[4], Rozenn Ravallec[2], Francois Coutte[2,4], Kimon Andreas Karatzas[1] and Paula Jauregi[*†]

The materials safety assesment: Inteligent system

- **Sensors spots:**
- O_2 (It is legally approved in the EU for direct contact with food),
- CO_2 (non contact),
- Amine sensor (pending

ofi

Expert Opinion under Austrian Food Legislation

This Expert Opinion replaces the one issued on 21 January 2019, 18 December 2019 and 25 May 2020

Expert Opinion No 1902071-2e **Date** 19 February 2021

Client TecSense GmbH
Teslastrasse 4
A-8074 Grambach
AUSTRIA

Application 24 April 2013, 2 November 2018, 20 November 2019 and 5 February 2021

Product(s) TS packaging spot
Formulation according to writings of 11 July 2013, 4 April 2013, 4 April 2018, 12 Nov. 2018, 4 Dec. 2018 and 12 December 2018

Description Polystyrene-based sensor spot for printing on film

Declaration

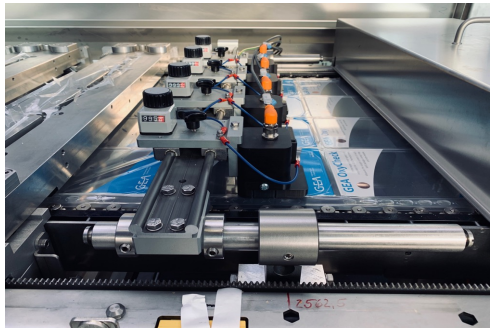
With regard to material composition, the requirements laid down in Art. 3(1) of Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food have been fulfilled.

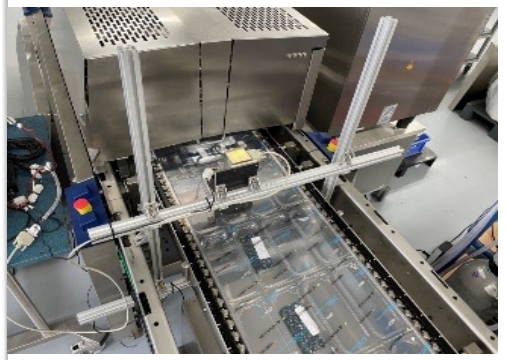
The products in question, in the composition disclosed and under the condition that they have been properly processed, are admissible materials in accordance with Art. 19(1) of the Austrian Federal Act on Food Safety and Consumer Protection (LMSVG).

The monomers on which the polymer components of the products are based, as well as any other starting substances, additives or production aids, correspond to the provisions of Arts. 5 and 6 of Commission Regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food (incl. supplements).

With regard to the requirements of Regulation (EC) No 450/2009 on active and intelligent materials and articles intended to come into contact with food, both migration tests for the colour components in the sensor spots (including a toxicological assessment of the results) and microanalyses regarding evidence of a depletion zone of the colorant near the surface of the sensor spots were performed – see TecSense OxyCheck Sensor Migration Study of 7 November 2018, as well as the study conducted on 9 August 2018 in cooperation with the University of Graz (Analysis Reports of 7 November 2018 and 9 August 2018); toxicological assessment of the migration results by toxicologist Dr. Karl Dobianer of 15 December 2018 (Contract No 2018-05-07a5V); test report of Josef Stefan Institute of 19 December 2018).

It has been established that the polymer component of the sensor spot is, in fact, designed to constitute a functional barrier for the integrated colorant in accordance with Section 5 (2c) in conjunction with Article 10 (1) of Regulation (EC) 450/2009; i.e. in areas near the surface with possible food contact, a barrier layer is formed that is free from colorants to the greatest possible degree (migration generally below 10 µg/kg of food).





The Materials Safety Assessment

Food safety regulations

Tray

TRAY				
Supplier	**Reference**	**Grade**	**Food Contact compliance**	**Pending information/remarks**
NatureWorks	Commercial PLA	Ingeo™ biopolymer 2003D	Compliance with Regulation (EU) No 10/2011 as amended. No SML´s for the above referenced grade exist	Rg (EU) No 10/2011 includes OML, should be measured in finished articles. No SML
ITENE	Clay for PLA	O2BLOCK 1200	Approved and listed in Annex I of Rg. (EU) No 10/2011.	No SML. For PLA matrix formulation.
Mitsubishi	PBS	BIO PBS FZ91PM	Approved by FDA (FCN No.1574) and JHOSPA, comply to Rg 10/2011.	Ensure the OML of 10 mg/ dm^2. SML of 1,4-butanediol and Tetrahydrofuran

OVERALL MIGRATION TESTS OF THE TRAY			
Test conditions	**10 days at 20°C (any food contact at frozen and refrigerated conditions)**		
Simulant	**Limit (mg/dm^2)**	**Result**	**Compliance with Reg (EU) No 10/2011**
A	10	0.1 ± 1.2 mg/dm^2	Yes
B	10	0.3 ± 3.7 mg/dm^2	Yes
D2 (iso-octane)	10	0.1 ± 0.0 mg/dm^2	Yes
D2 (ethanol 95% v/v)	10	0.1 ± 1.8 mg/dm^2	Yes

Polyester amine PEA

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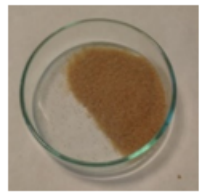
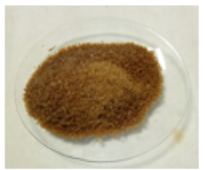
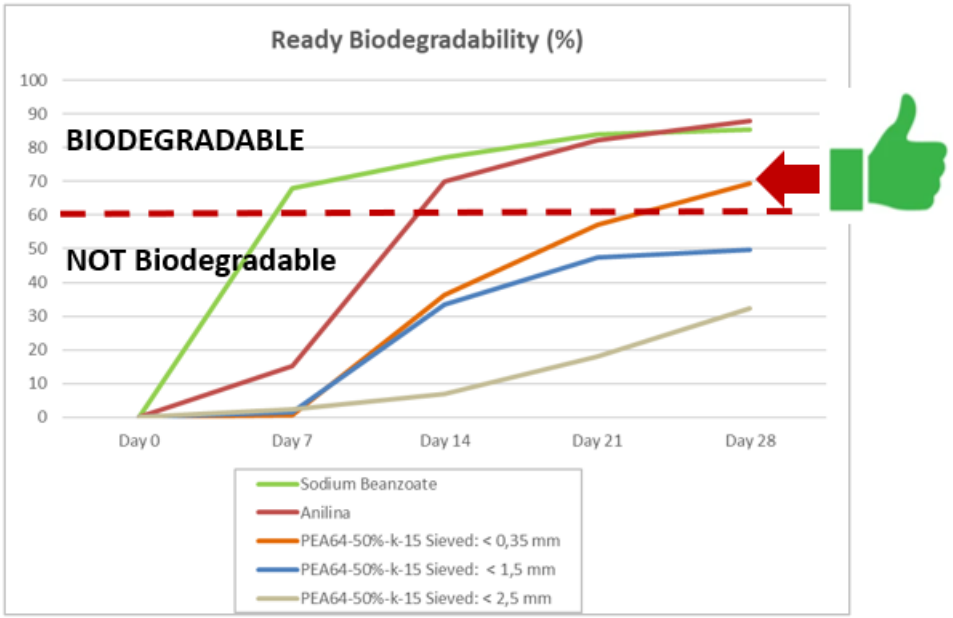
Ecotoxicity, biodegradability and LCA studies

RESULTS: Aquatic Biodegradability

- **Test method:** OECD 301F Method, manometric respirometry (oxygen consumption).
- **Reference compounds**: Aniline and Sodium benzoate
- **Sample:** PEA-1 taking into account the sample size (sieving for getting 3 sample sizes)







- **PEA64-50%-k15 sieved <0,35 mm** is the only sample that fulfils the 60% of Biodegradability requirement.
- **Sample size does matter** in biodegradability performance of PEA material. The lower the size, the better biodegradability results

Polyester amine PEA

BIOSMART

Ecotoxicity, biodegradability and LCA studies

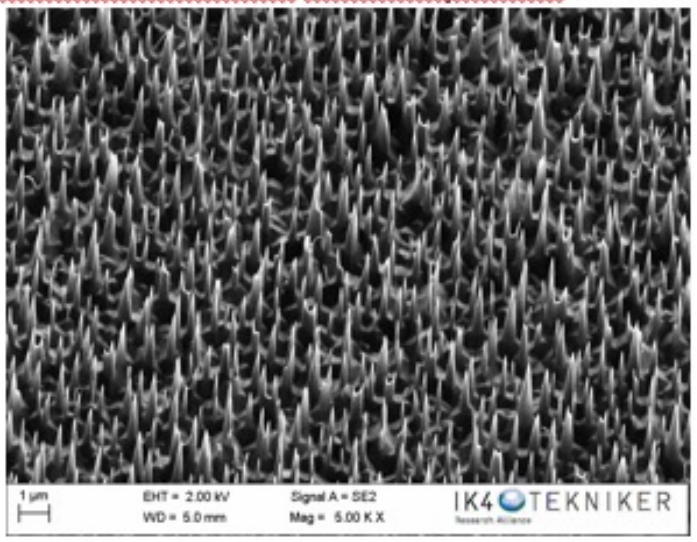
RESULTS: Aquatic Ecotoxicity

- **Sample:** PEA 1, 64_50%, WAF fractions obtained after stirring
- Solubility test showed that **100 g/l** solution was the most saturated and stable one.

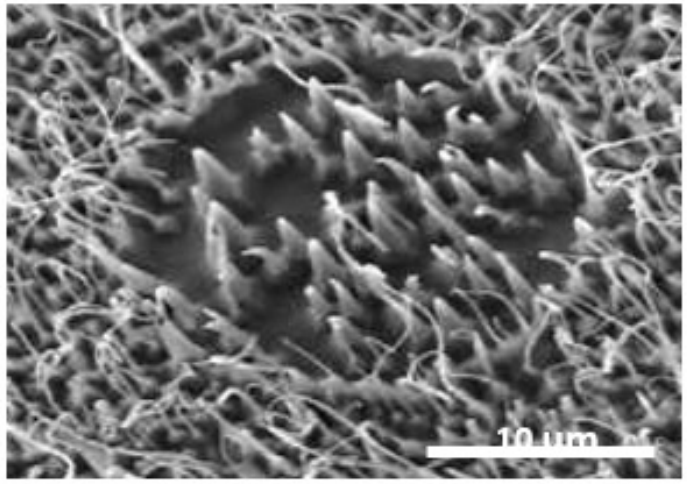
	EL_{50}	
	PEA	**UV light aged PEA**
Alga Growth Inhibition test (OECD 201)	>1000 mg/l	>1000 mg/l
Daphnia Magna Acute Immobilization Test (OECD 202)	>1000 mg/l	>1000 mg/l
Vibrio Fischeri: Bioluminiscence inhibition assay (ISO 11348-2)	>1000 mg/l	>1000 mg/l
TOXICITY classification	NOT TOXIC	NOT TOXIC

Texturing hydrophobic properties

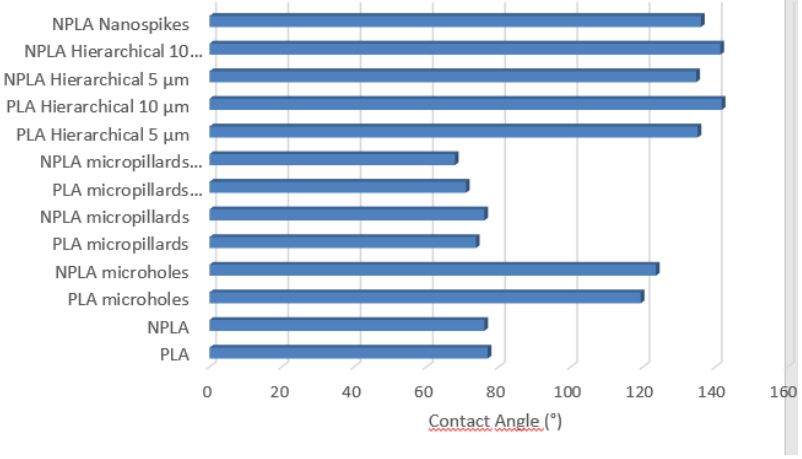
Antibacterial nanospikes in SiO_2



Nanospikes replica in PLA by NIL



1. Topographies with hydrophobic properties



UV protective coatings

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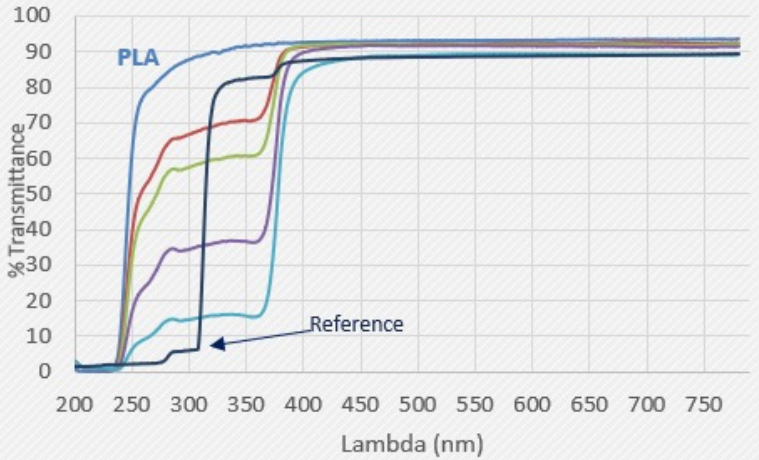
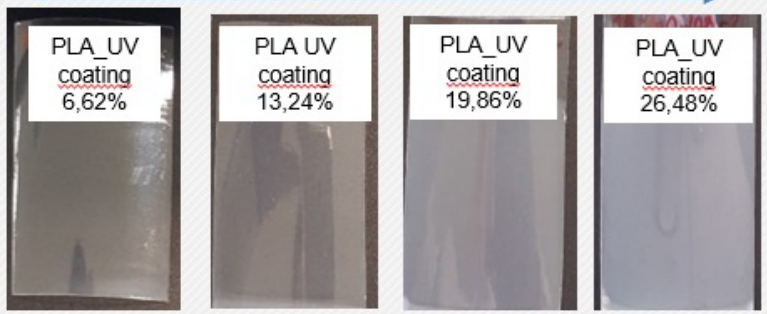
2. Barrier coatings for UV protection

ITENE



Milky colour



- Solgel and biobased coatings with dispersed oxide nanoparticles.
- Deep coating and spray application
- Scalable UV barrier

(migration of the metal should be <5 mg /kg)

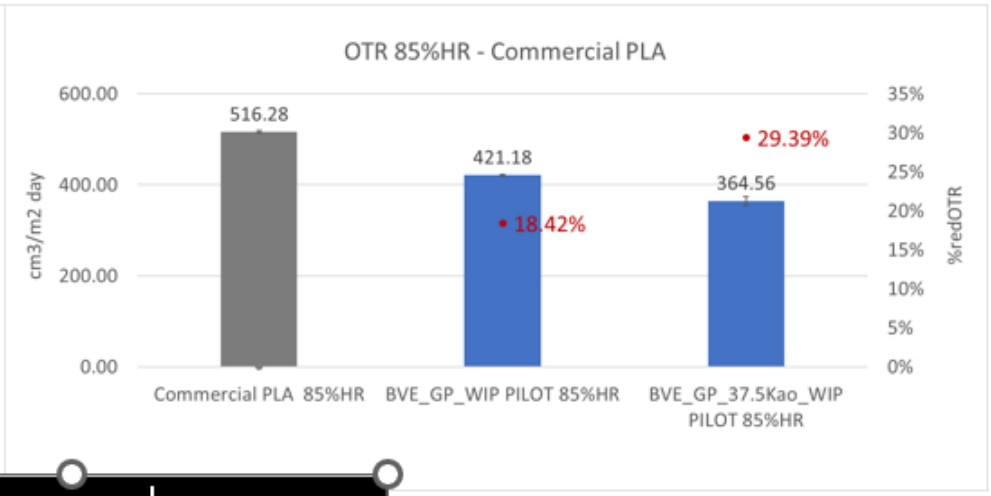
L 230/22 EN Official Journal of the European Union 25.8.2016

COMMISSION REGULATION (EU) 2016/1416

of 24 August 2016

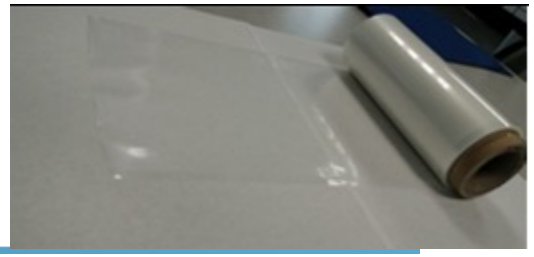
amending and correcting Regulation (EU) No 10/2011 on plastic materials and articles intended to come into contact with food

Water and oxygen barrier coatings



Food approval, biodegradable

Nanocomposite coating_WIP PILOT Improvement vs comercial PLA	
OTR (**0%RH**) ASTM D3985	OTR (**85%RH**) ASTM D3985
99.27%	**29.39%**



Antimicrobial properties

BIOSMART

Antibacterial tests

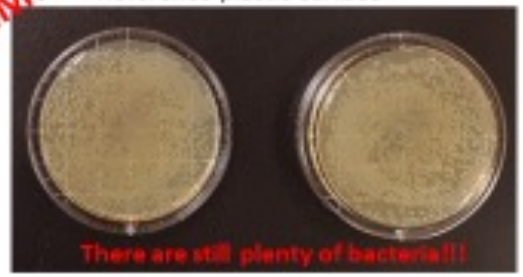
Antibacterial tests: ISO 22196:2011 – Measurement of antibacterial activity on plastics and other non-porous surfaces

- ✓ Novel methodology was adopted to assess the antibacterial features of BIOSMART materials
- ✓ Adaptation of the experimental procedure described in JIS Z 2801:2012/ISO 22196:2011 standards.
- ✓ The main change is related with the bacteria recovery method: instead of a using a solution of the SCDLP neutralizer, a method based on contact plating is adopted.

WHY?

PROBLEM!!!

Reference plastic surface



Commercial plastic samples: AUTOTEX AM

PROBLEM!!!

Claim antibacterial effect by ISO 22196

Antimicrobial properties

BIOSMART

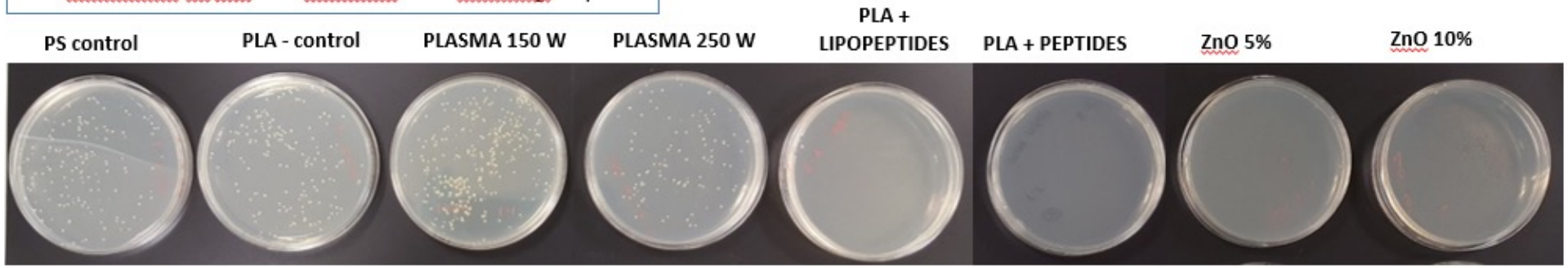
Antibacterial tests

RESULTS

Evaluation of the cover film in contact with materials by contact plating

NO Bactericidal! NO Bactericidal! NO Bactericidal! NO Bactericidal! Bactericidal! Bactericidal! Bactericidal! Bactericidal!

Evaluation of the PBS solution after washing step



Bacteria is present on control groups

No bacteria is present in the PBS used for washing the bactericidal samples

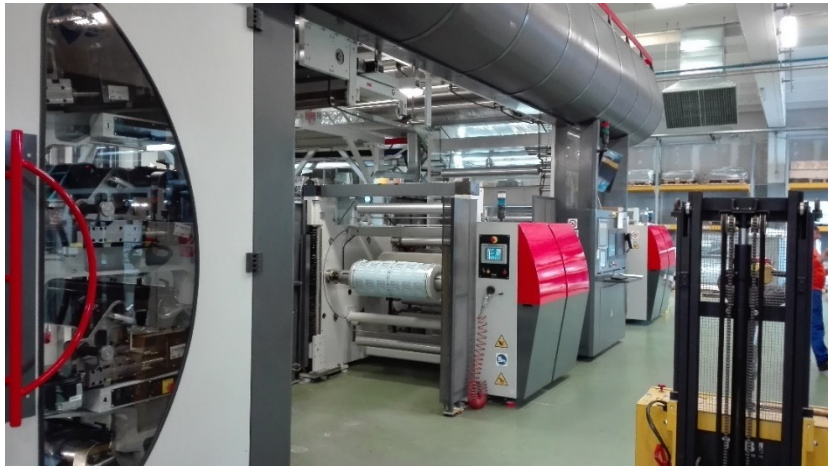
The scale up

The most developed technologies (TRL5, our initial goal) was integrated in final packaging **at industrial relevant conditions** (TRL6).

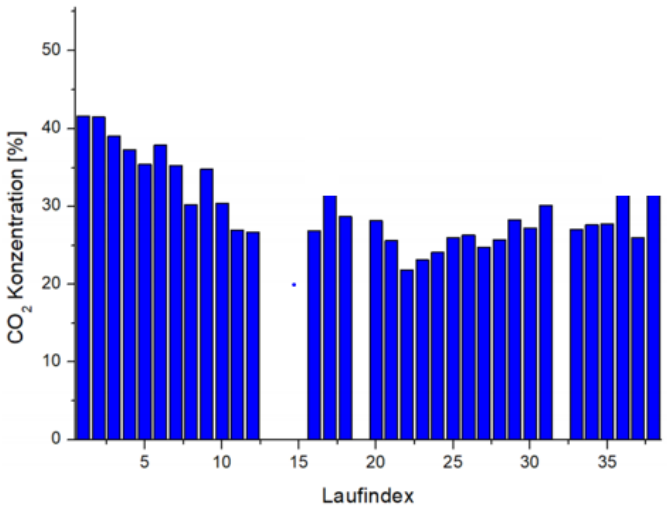
This was necessary **to perform consumer acceptance tests** requiring **large number of industrial packaging,** with a **big effort of the entire Biosmart team.**

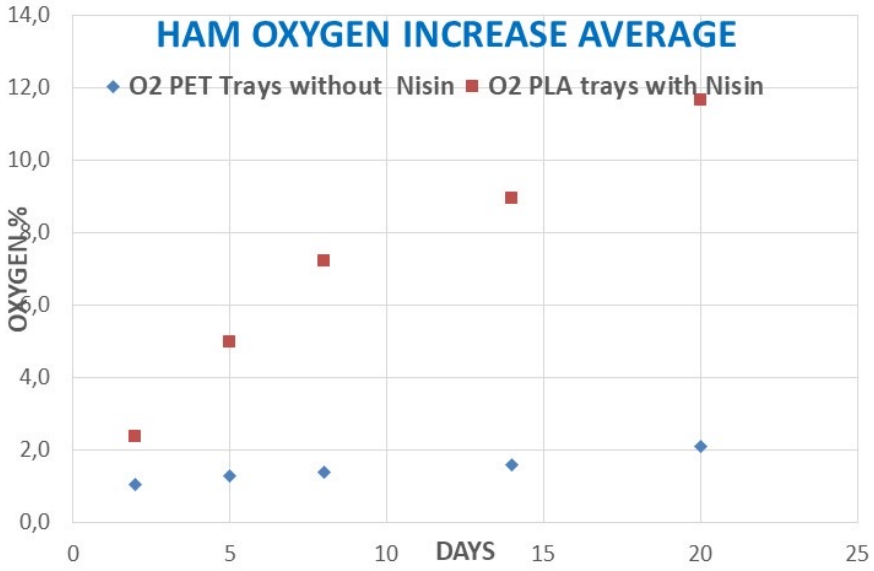
For **each trial under production conditions,** at least 1000 m of thermoforming sheet for the trays and 1200 m of top sheet are needed. 100 - 200 m are needed in minimum to set up the printing and packaging machines.

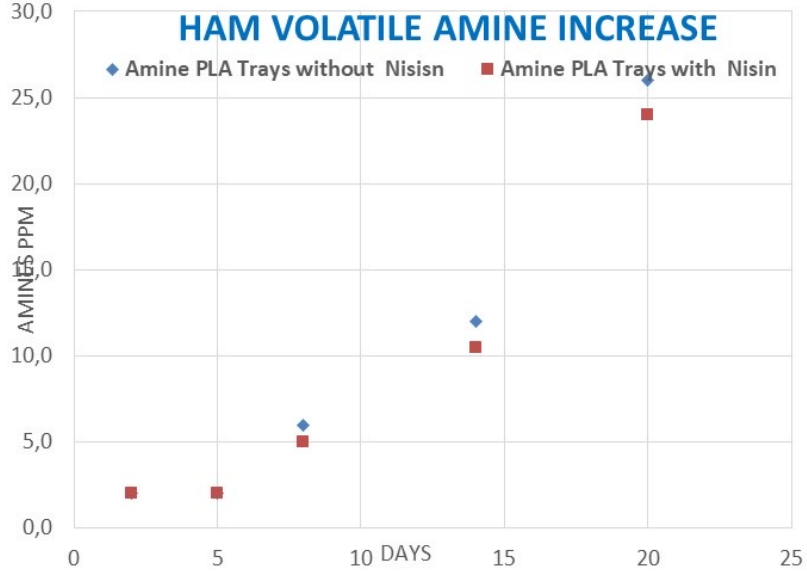
There is **still much development work to be done (TRL5-7),** which can be continued on the basis of what has been achieved till now.



The sensor monitoring of food self-life ham packaging







The sensor monitoring of food self-life cheese packaging

BIOSMART

Sensor system close to serial production

Cheese PLA / PET packages packed 2021_10_14

- Influence of Mycosubtilin clearly visible
- PLA with Mycosubtilin day 16 no mold
- Without Mycosubtilin mold visible at day 16, very pronounce at day 38

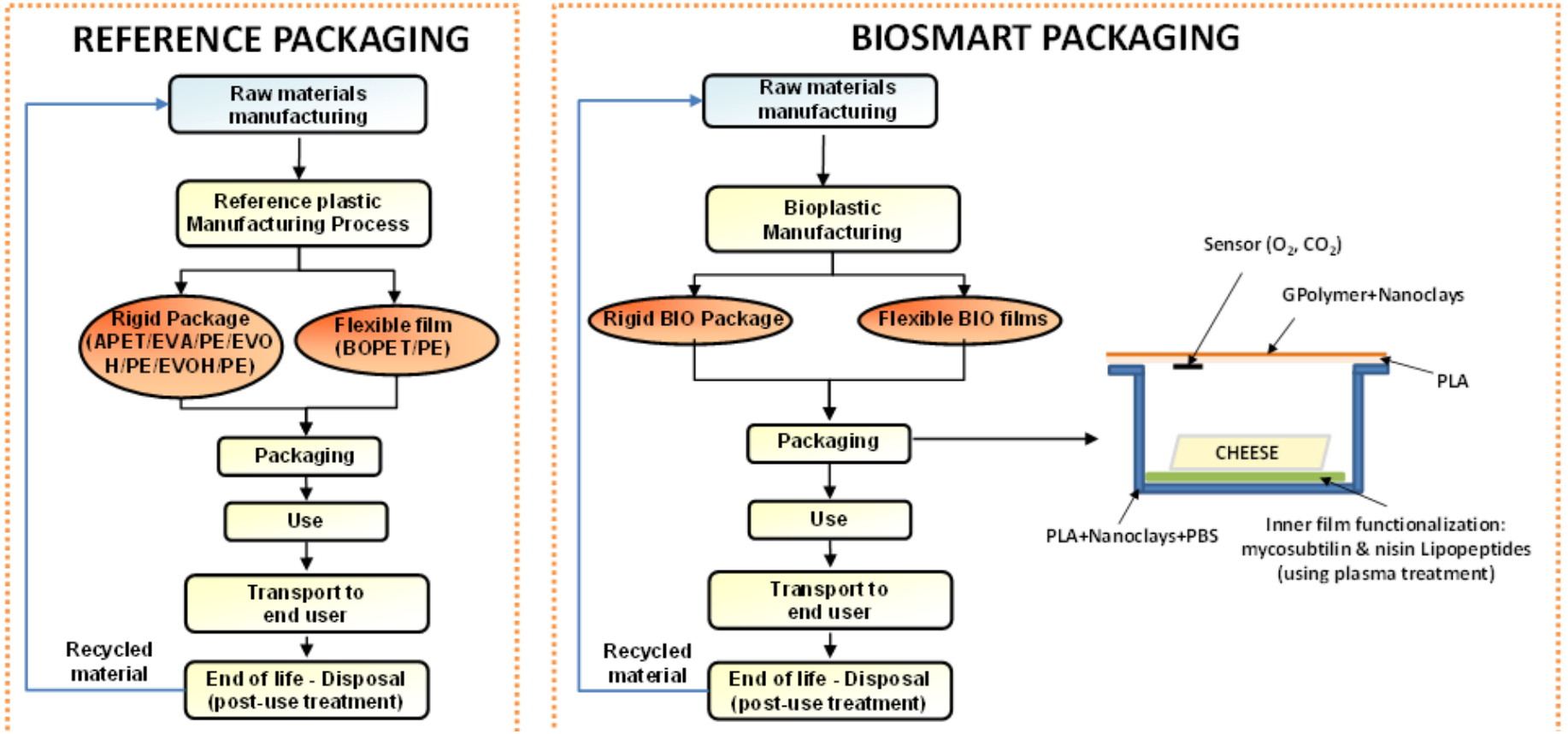
Cheese packages PLA without / with Mycosubtilin / PET day 38

Lifecycle Environmental Assessment

1 kg produced or packaged food as a functional unit.

RESULTS: Lifecycle Environmental Assessment

Step 1: Goal and scope definition



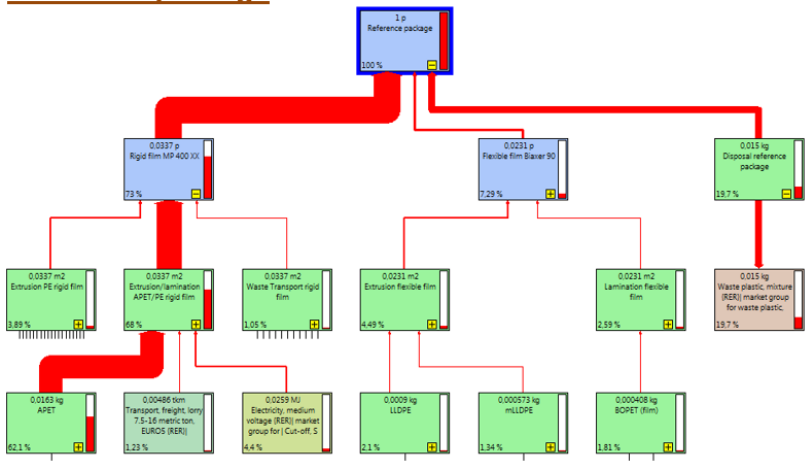
Lifecycle Environmental assessment

1 kg produced or packaged food as a functional unit.

RESULTS: Lifecycle Environmental Assessment

Step 4: Interpretation

Reference package

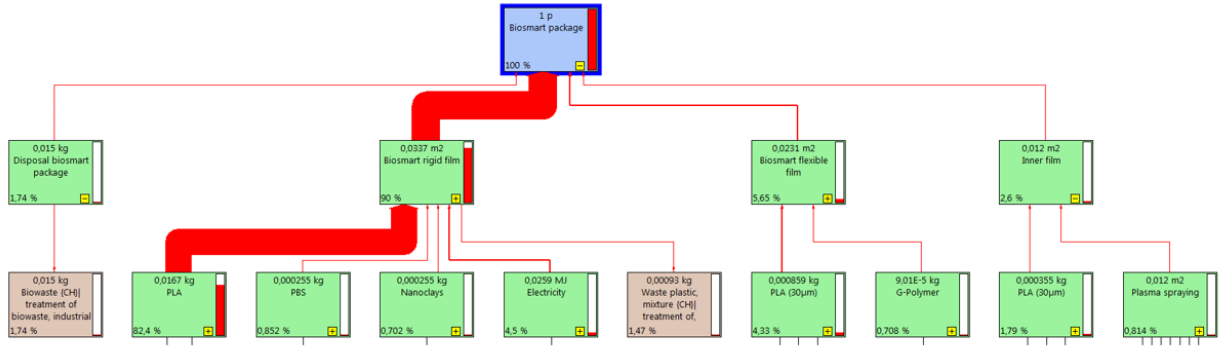


Main environmental impacts of rigid film manufacturing process are due to the production of the **APET** needed to manufacture the rigid tray

RESULTS: Lifecycle Environmental Assessment

Step 4: Interpretation

BIOSMART package



Main environmental impacts of rigid film manufacturing process are due to the production of the **PLA** needed to manufacture the rigid tray

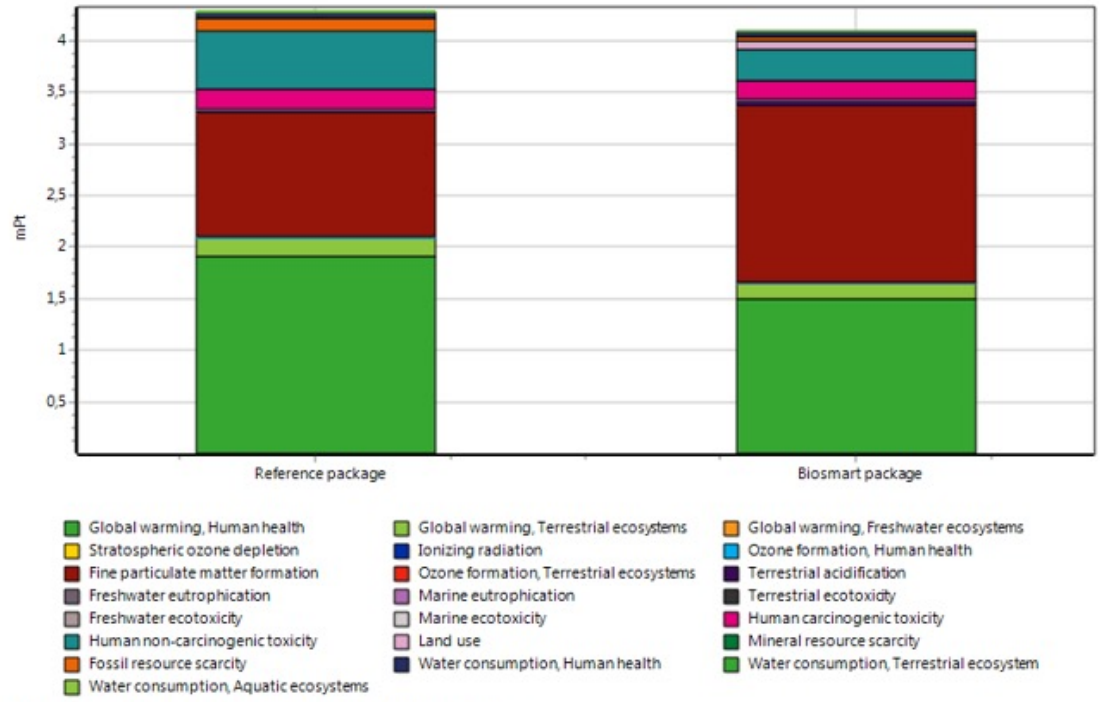
Lifecycle Environmental Assessment

1 kg produced or packaged food as a functional unit.

RESULTS: Lifecycle Environmental Assessment

Step 4: Interpretation

Reference Package *vs* Biosmart package



Method: ReCiPe 2016 Endpoint (H) V1.04 / World (2010) H/A / Single score
Comparing 1 p 'Reference package' with 1 p 'Biosmart package';

Method ReCiPe 2016	Unit	Reference package	Biosmart package	Impact reduction
	mPt	2,970	2,904	**2%**

Global warming	Unit	Reference package	Biosmart package	Impact reduction
	CO_2 eq	0,082	0,066	**19%**

The total environmental impacts associated to the BIOSMART package (including production and disposal) are lower than the impacts of the REFERENCE package.

Lifecycle Assessment impacts

125g of consumed cheese, including the necessary package to protect this cheese for the defined shelf life before its consumption

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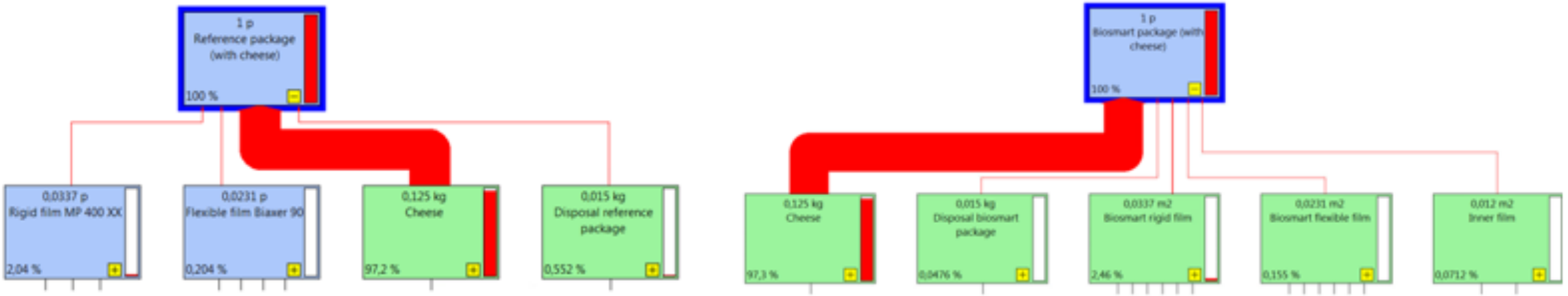
Case 2-Biosmart & REFERENCE package including cheese impacts

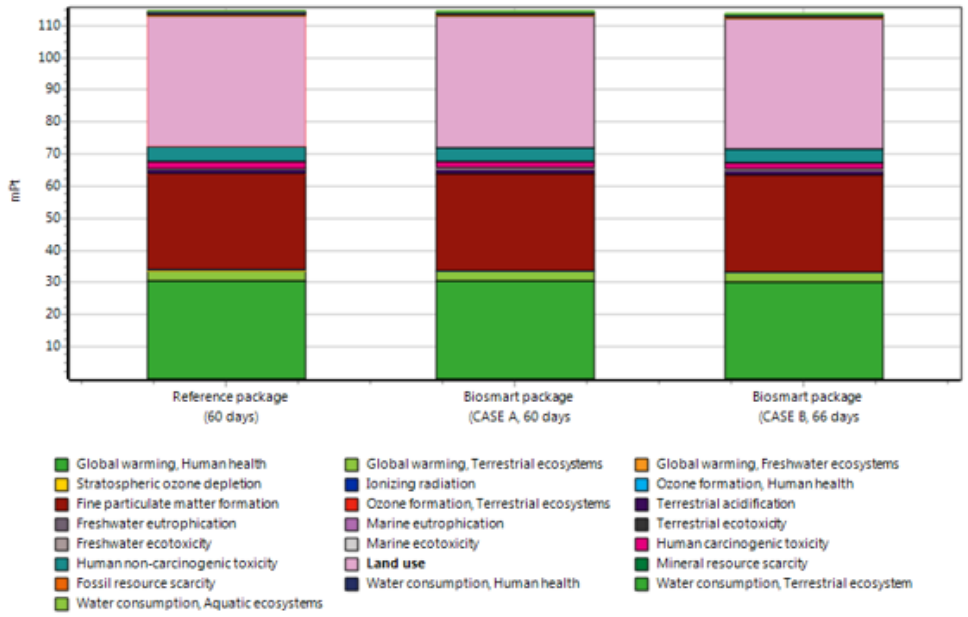


The **cheese** is the responsible for more **than 97%** of the package environmental impact.

Lifecycle Assessment impacts

125g of consumed cheese, including the necessary package to protect this cheese for the defined shelf life before its consumption

HYPOTHETICAL STUDY: BIOSMART & REFERENCE package including cheese impacts



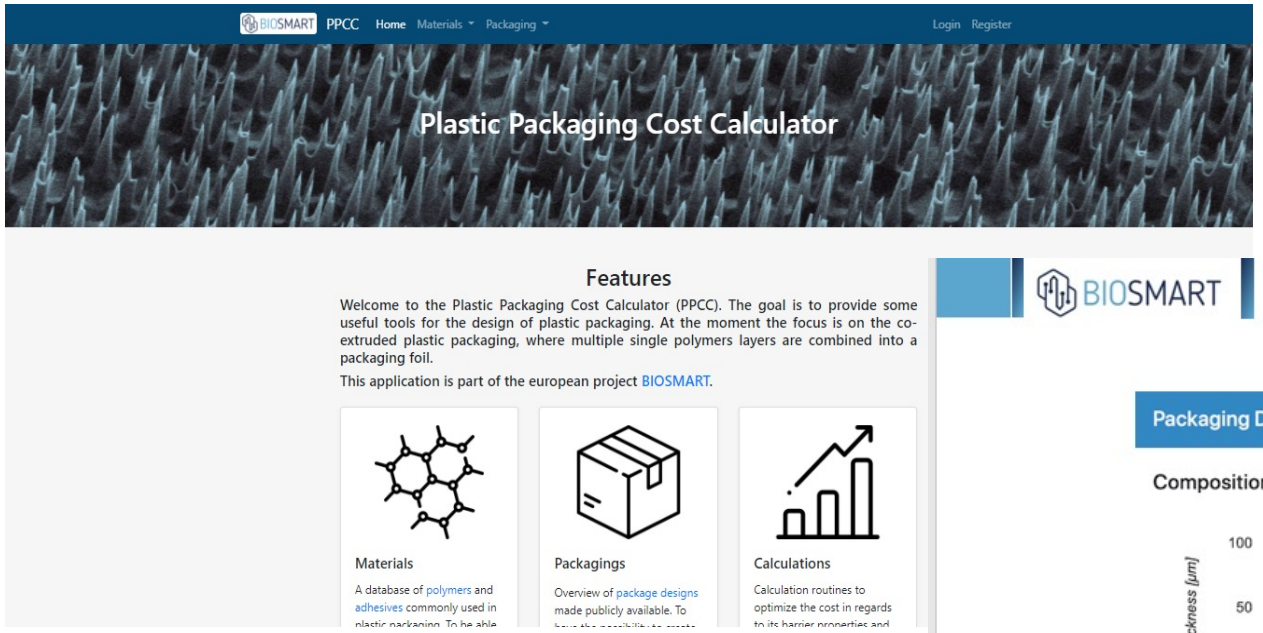
Method: ReCiPe 2016 Endpoint (H) V1.04 / World (2010) H/A / Single score
Comparing 1 p 'Reference package (60 days)', 1 p 'Biosmart package (CASE A, 60 days)' and 1 p 'Biosmart package (CASE B, 66 days)';

Damage category (ReCiPe 2016)	Unit	Reference package (60 days)	Biosmart package (CASE A, 60 days)	Biosmart package (CASE B, 66 days)	BIOSMART Impac Reduction when comparing with reference	
					CASE A	CASE
Total	mPt	114,5	114,5	113,8	**0,1%**	**0,7%**
Human health	mPt	68,1	68,1	67,6	0,1%	0,7%
Ecosystems	mPt	45,8	45,9	45,6	-0,1%	0,5%
Resources	mPt	0,6	0,5	0,5	9,3%	9,9%

Wobal warming	Unit	Reference package (60 days)	Biosmart package (CASE A, 60 days)	Biosmart package (CASE B, 66 days)	BIOSMART Impac Reduction when comparing with reference	
					CASE A	CASE
	CO_2 eq.	1,81	1,80	1,78	0,9%	**1,5%**

- **CASE A** (Biosmart and Reference same shelf life 60 days): almost **no differences** in the total environmental impact, but in global warming **the reduction will be 0,9%.**
- **CASE B** (Biosmart shelf life 66days; reference 60 days): A reduction of **0,7%** in the total environmental impact is achieved and in global warming **the reduction is 1,5%.**

Cost Analysis



The exploitable RESULTS

- Improvements of the PLA material mechanical and barrier properties concerning thermoformability Pilot scale production of the materials. ITENE
- Surface texturing (hydrophobic coatings), phase change materials and UV barrier coatings, new protocol to evaluate antimicrobial properties, ecotoxicity, biodegradability and Lifecycle Environmental Assessment. TEKNIKER
- Synthesis of PEA (FRI) and thermoforming surface adhesion of nisin, lipopeptides by plasma and scale up and APLICATION to predict barrier properties, FRIBOURG
- Antimicrobial, antifungal, and antioxidant lipopeptides studying cytotoxicity and food approval. Pilot scale production of lipopeptides, evaluation of packaged samples. LILLE, LIPOFABRIC, Univ. READING
- Development of measurement methods for non-invasive quality control and integration into packaging machines. TECSENSE, GEA
- Evaluation of packaging materials and packaged food from the microbiological and consumer's point of view, RISE.
- BioSmart polymer films. WIPAK

Benefits to society and the environment

Benefit 1: Food grade (EFSA) approved biobased plastic (Polylactic acid reinforced with nanoclays) compostable with 20% enhanced mechanical and barrier properties. The food residual and packaging can be jointly composted.

Benefit 2: Sensors (oxygen, CO_2, amine) to monitor food self degradation in modified atmosphere packaging. The O_2 and CO_2 sensors can provide 100% on-line packaging control. EU Food approval and Solar Impulse Solution Efficient label obtained for oxygen sensor. **Zero defects** during packaging manufacturing can reduce the food lost in the value chain.

Benefit 3: The food waste and packaging can be compostable or be **transformed to biogas generating energy and heat** in combustion engines using cogeneration.

Benefit 4: The retailer and maybe in the future the consumer will be able **to monitor the food degradation** to control the food self life limits, reducing the food waste and the CO_2 emissions

Contribution to EU policy

- The BIOSMART **biobased compostable packaging** is based on Polylactic (sourced from corn, sugar) improving mechanical properties by reinforcing with nanoclays. The use of biobased packaging will contribute to Green Deal Objectives **reducing the carbon footprint.**
- The **use of sensors** for control food selflife in biobased food packaging is **aligned with the Farm to Fork Strategy.**
- The **increase of food self-life** using biobased antimicrobials and antifungal will **reduce food waste,** eliminating pollution of soil and CO_2 emissions, and it is **fully aligned with Sustainable Agriculture and Climate Action**

Next steps

- Study alternative biobased material Solutions for packaging
- Scale up TRL5-7 packaging smart solutions developed
- Scale up the cost of amine sensor spot, and get the food approval
- Increase barrier protection of biobased Solutions
- Implement recyclable materials in packaging
- Enlarge the number of packaging applications

BIOSMART
BIOMATERIALS FOR SMART FOOD PACKAGING