Innovative fully biodegradable mulching films and fruit protection bags for sustainable agricultural practices

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INTERNATIONAL CONFERENCE ON PLASTIC FILM TECHNOLOGIES USED IN AGRICULTURE, SILAGE, MULCH, GREENHOUSE AND TUNNEL FILMS

26-28 SEPTEMBER 2017, CROWNE PLAZA BARCELONA FIRA CENTER, BARCELONA

Organised by: AMI

Sponsored by: DOW, Braskem, ExxonMobil

Media supporter: Film and Sheet EXTRUSION

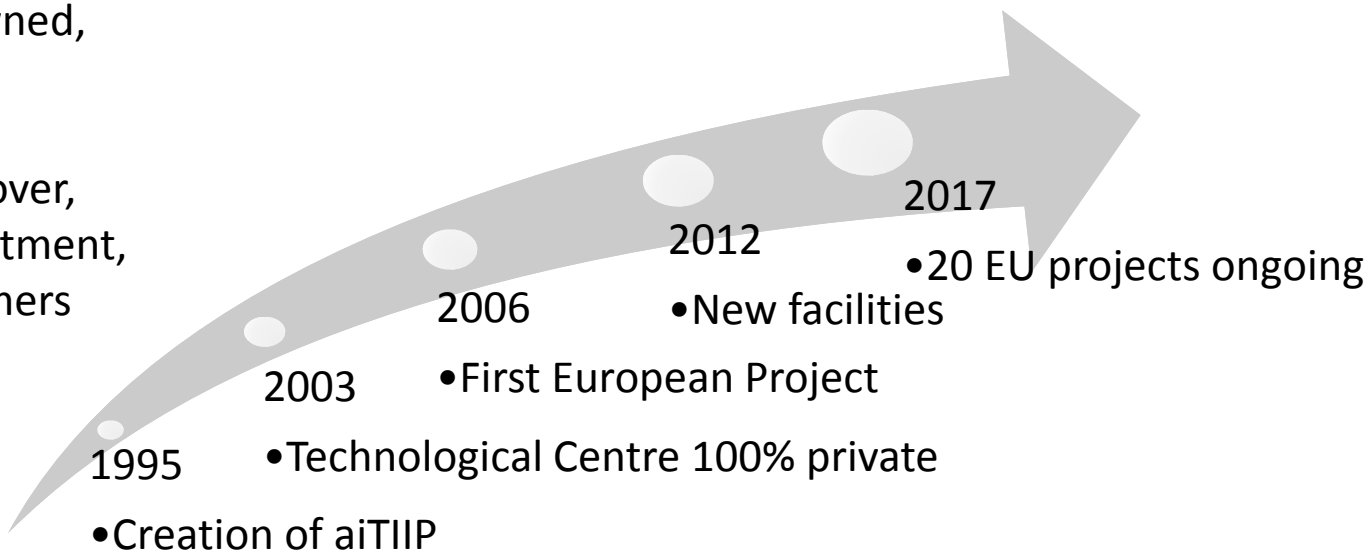
1. Our organization

Key Activities

AITIIP is a private technological centre whose goal is to increase the competitiveness of companies in the industry of moulds and plastic parts manufacturing.
AITIIP offers advanced technology services to other companies (62% of the income), performs research, development and innovative actions (37% of the income) and training and e-training aitemy (1%).

Key Figures (2016)

100% privately owned,
49 employees,
12,000 m2
7 M€ annual turnover,
1 M€ annual investment,
175 annual customers



For more information please visit: www.aitiip.com

1. Our organization

Membership

Member of the Technical Committee for Standardization / Normalization ISO working group of additive manufacturing / 3D printing
Associated Member of Biobased Industry Consortium
Member of European Factories of the Future Research Association

Results (2016)

25 own projects in R&D
75 projects of research, technological development and innovation and collaborative agreements with companies
250 technological services for enterprises

European projects (2016)

Circular Economy

- Agricultural waste valorisation
- Biopolymers
- Green composites

Industry 4.0

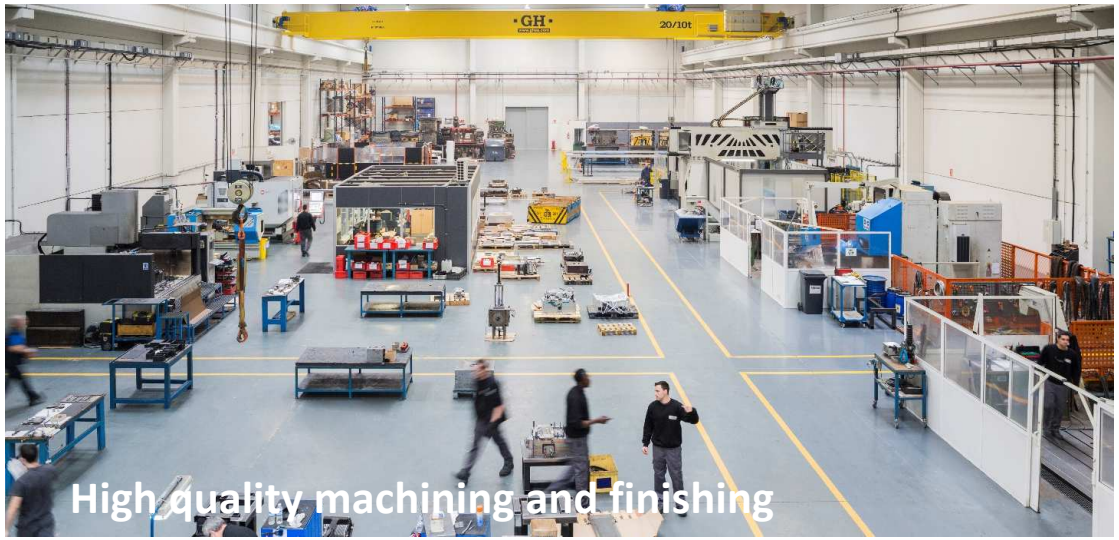
- Multi-material additive manufacturing and 3D printing
- Robotization of processes

Main Sectors

Automotive
Aeronautic
Agroindustry & Food Packaging

For more information please visit: www.aitiip.com

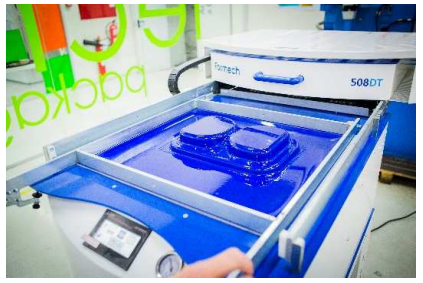
Plastic Injection

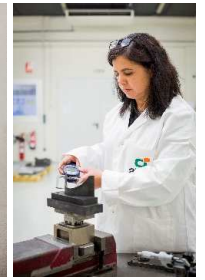


High quality machining and finishing

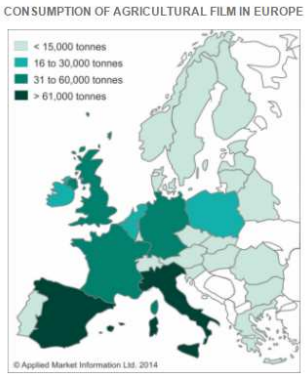

3D Printing

Semi-industrial machinery for processing of materials and Mechanical tests Laboratory





2. Purpose of this line of investigation



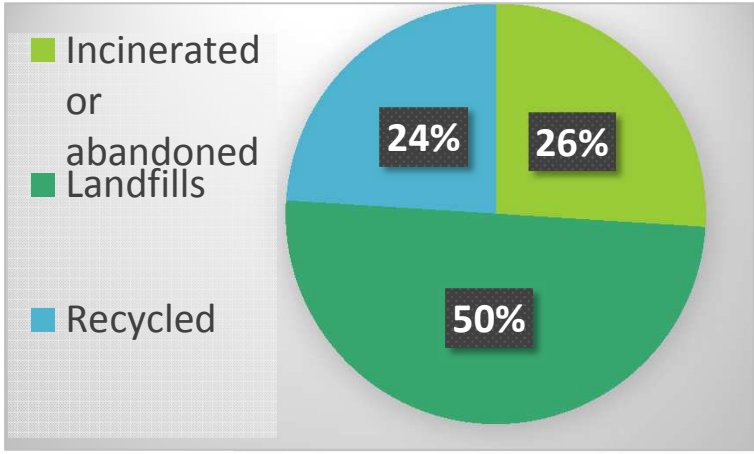
Current semi-intensive and intensive farming practices require the use of large quantities of plastic film and paraffin wax paper.

These practices have a significant environmental impact:

- Single use only
- Elimination involves high costs in terms of time and money

Environmental consequences if not removed correctly

1. High economic and environmental impact in the use of conventional plastics and fossil energy (50% is disposed of in landfill).
2. HDPE-LDPE material abandoned in landfills or open fields may take about 100-500 years to break completely.
3. Loss of harvested products due to improper use, soil loses fertility (less nitrogen fixation and nutrients) and lead to erosion as a result of concentrated runoff. Some plastics contains traces of heavy metals, phthalates…



2. Purpose of this line of investigation

Protected Designation Origin

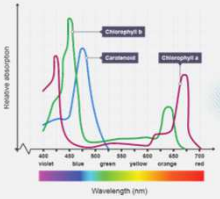
Agroplastics are needed:

Innovations **Sustainable**

- Conserve water and nutrients
- Prevent weed growth
- Permit adequate temperature in the rhizosphere

Trace elements

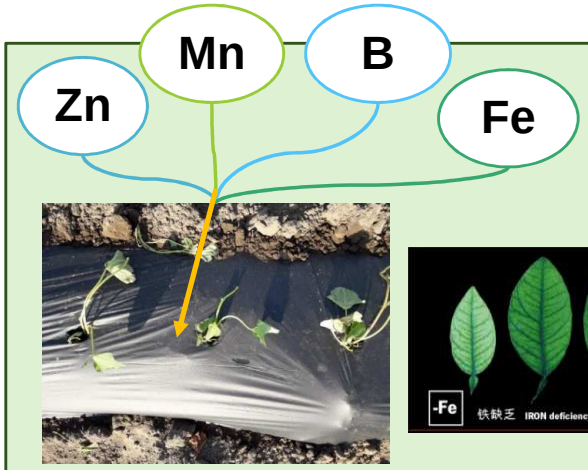
- Protection against pests and infestations
- Isolate fruit from plant protection products
- Fruit with uniform skin colour



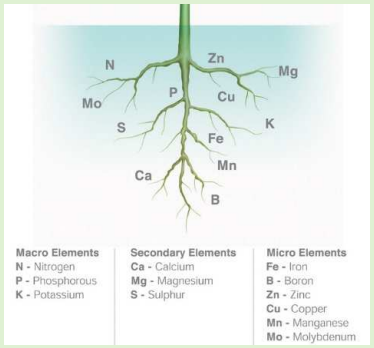
Macro-perforations
Coloring bags

Biodegradable films deliver the same positive agronomical effects as conventional ones, additionally, they offer additional advantages at the end of the crop cycle because they can simply be left on the field and ploughed under.

The overall objective of the project is to demonstrate that the **sustainability and efficiency of agricultural practices** can be achieved by introducing an **innovative**, economically viable and soil biodegradable plastic that **eliminates waste** completely.



Mulching Innovations

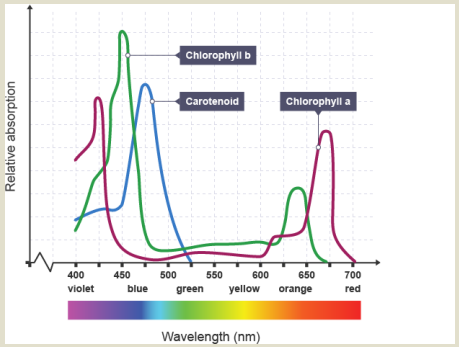


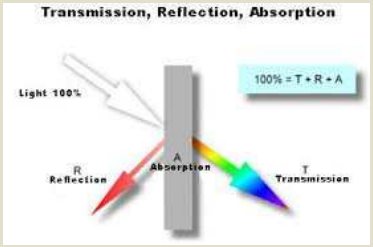
Plastic Legislation

Fertilizer value

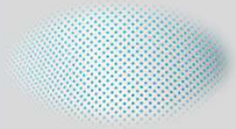
- **Iron** deficiency is the main lack in crops under plastic (chlorosis)
- **Boron** deficiency appears in dry climates (important for plant metabolism)
- **Zinc** is required by many enzymes (hormone auxin, little leaf)
- **Manganese** is necessary for photosynthesis (coloration)

Fruit protection bags innovations





Photosynthetically Active Radiation (RFA) *amount of integrated radiation in the range of wavelengths that are capable of producing photosynthetic activity in plants.*



Micro perforations *to prevent rotting due to the concentration of water vapour inside the bag.*

3. Demonstration Character

Raw materials
-100% biodegradable
-Polymers based on natural sources

Production processes
-Materials extrusion
-Film blowing

Validation of plastics products in fields
-Tomato (Spain and France), pepper and cucumber in Spain and sweet potato in Belgium
-Bags for apple and peach (Spain)

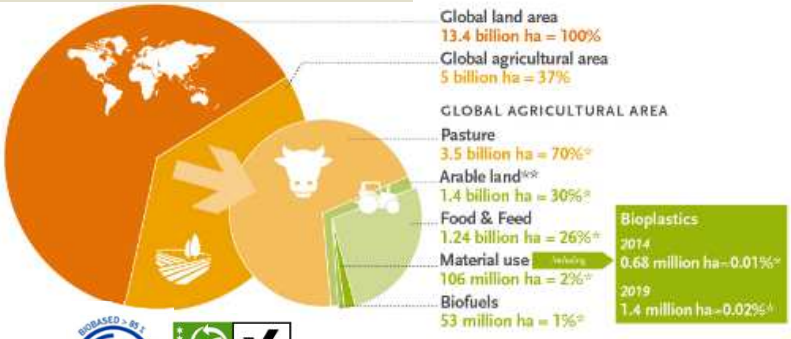
Validation of plastics in laboratory
-Mechanical tests of materials
-Tests for certification OK BIODEGRADABLE SOIL

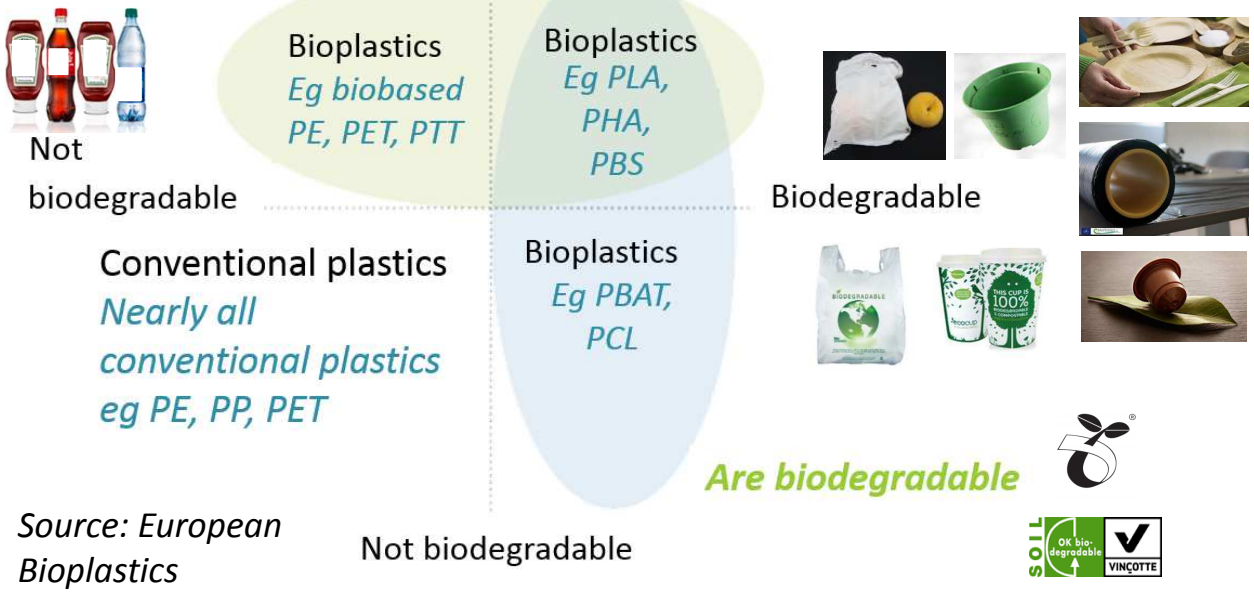
Validation of quality:
- Soil
-Crop (Pre-harvest)
- Product (Post-harvest)

Expected results
- Reduction of plastic waste
- Less CO_2 emitted during the production of plastics/Non-emissions from disposal
- Improvement of soil quality
- Improvement in crop quality
- Certification OK BIODEGRADABLE SOIL

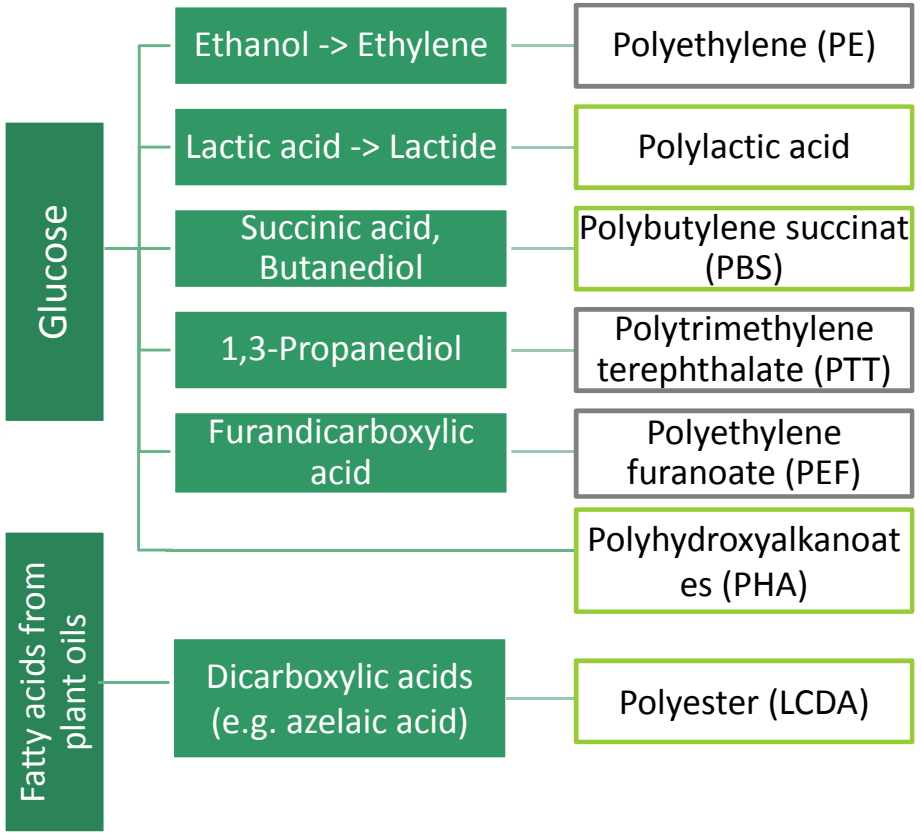
4. Raw Materials

Renewable origin (biobased) refers to the origin of carbon atoms in polymers.





Source: European Bioplastics



Biodegradation by microorganisms is a matter of polymer structure, not of carbon origin. Not oxo-biodegradable (Chemical degradation).

5. Transformation processes

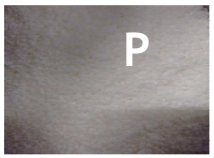
1 Extrusion compounding

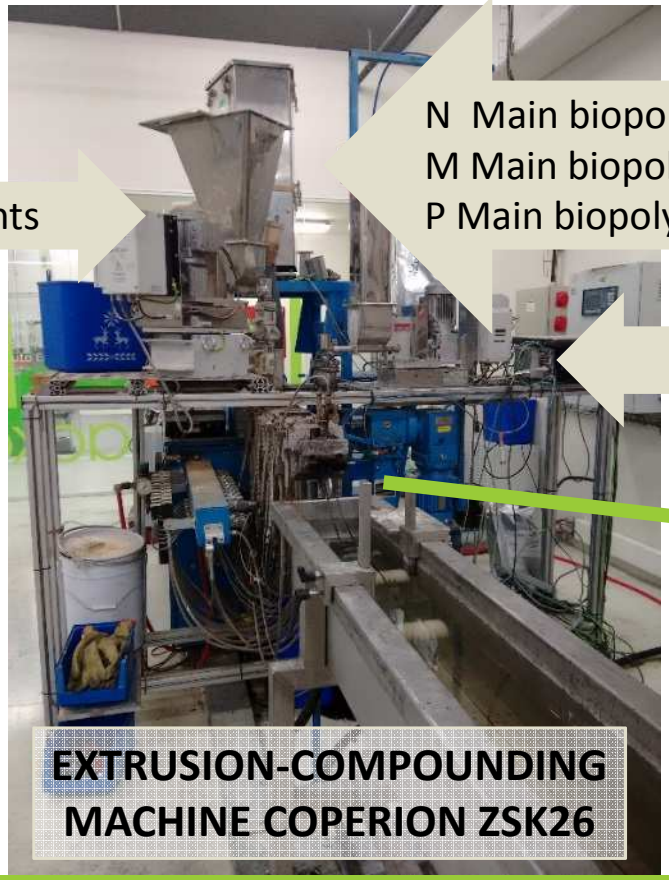
Twin-screw extruder equipped with one gravimetric dosing for pellets, two for powder and one for liquids (1 to 100 Kg/h)

- Pelletizer and dryer on the same line.
- Adapted screws for several materials and additives
- Ultrasonic system of dispersion available

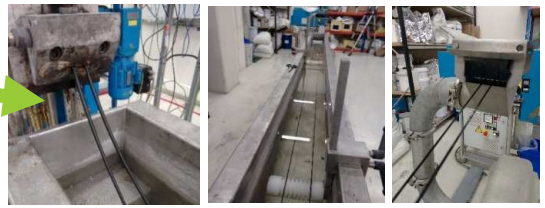
Oligo elements

N Main biopolymers AAPE
M Main biopolymer PHA-PLA
P Main biopolymer PBS





Carbon Black



- ✓ Tª control
- ✓ Material flow control
- ✓ % components

EXTRUSION-COMPOUNDING MACHINE COPERION ZSK26

Moretto X DRY AIR T Minidryers

5. Transformation processes

2 Film blowing

Film blowing unit LABTECH LF 400 for film production

- ✓ Air speed control
- ✓ BUR control
- ✓ Height of the equipment
- ✓ Roll speed

- Different layer configurations 3-layer (bi material: ABA), 2-layer (AB or BA) and monolayer
- Max film width output: 800 mm
- Blow ratio up to 3,5
- Thickness from 10 µm depending on material

3 Technical measurements

Thickness

Width

Dispersion

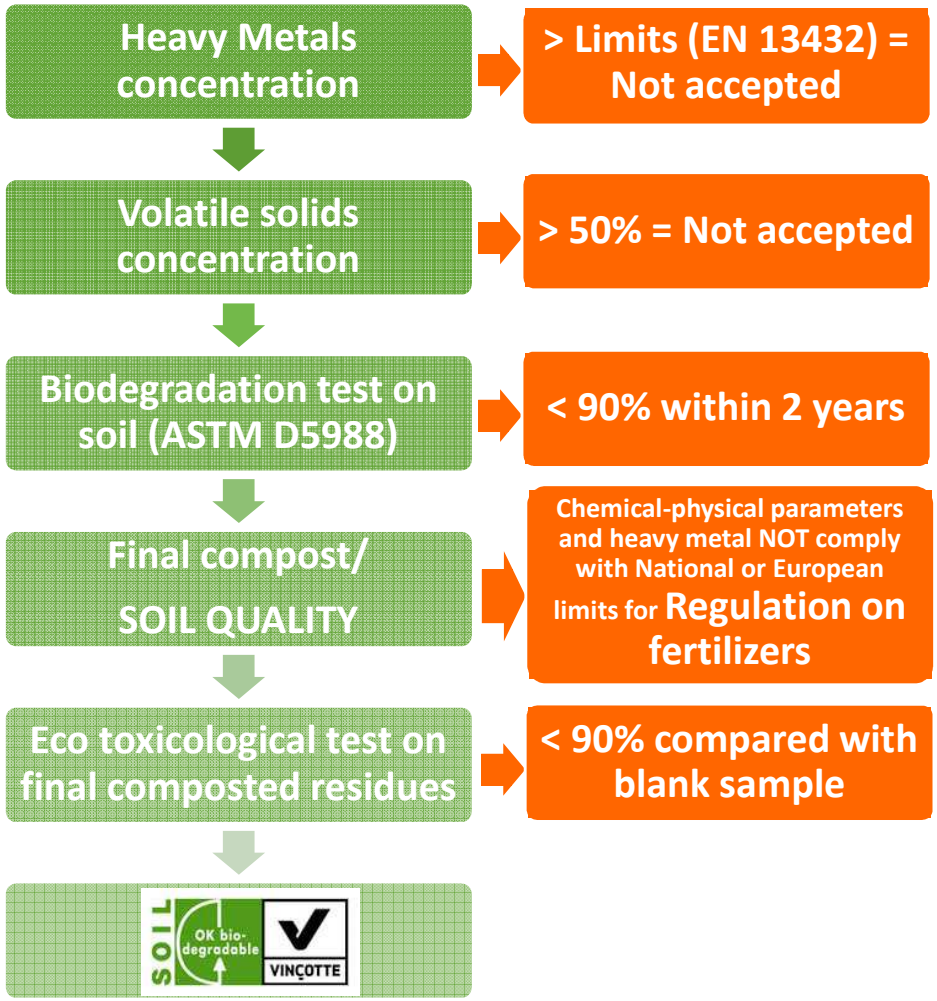
Mulching

Film for fruit bags

Samples (materials)			Thickness
MULCHING 3% oligoel.	M	M1-M3	2 thickness
	N	N1-N3	3 thickness
	P	P1-P3	1 thickness
FRUIT BAGS 2% and 2 different colour	M	M4-M7	40 µm
	N	N4-N6	35 µm
	O	O1-O3	50 µm

6. Laboratory plastics validation

BIOPLASTICS CHARACTERIZATION	Method
Tensile Properties of Thin Plastic Sheeting	ASTM D 882 – 12
Tear-Propagation Resistance of Plastic Film and Thin Sheeting by a Single-Tear Method	ASTM D 1938 –14
Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials	ASTM D 790 – 15
Plastics – Methods of exposure to laboratory light sources	EN:ISO 4892-3
Standard Test Method for Oxidative-Induction Time of Polyolefin by Differential Scanning Calorimetry	ASTM D3985 - 10
Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor	ASTM F1249 - 13
"OK Biodegradable Soil"	EN13432:2000

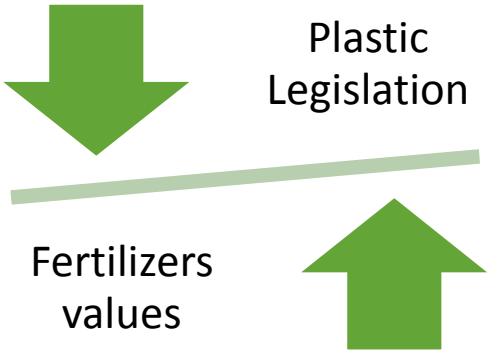


6. Laboratory plastics validation

Heavy metals content in plastic samples

Heavy Metals concentration → > Limits (EN 13432) = Not accepted

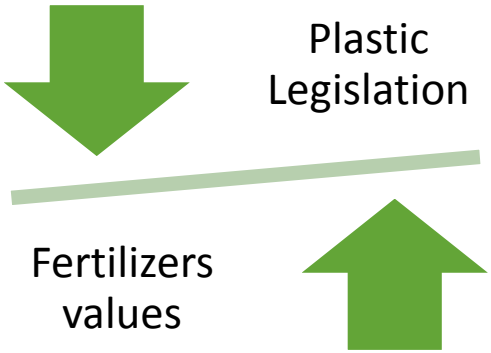
- **EN 13432:2000: Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging.**
- ***UNE-EN 14995:2007*** *Plastics. Evaluation of Compostability. Test scheme and specifications.*
- ***prEN 17033:2016 Plastics - Biodegradable mulch films for use in agriculture and horticulture - Requirements and test methods.***



	As	Cd	Cr	Hg	Mo	Ni	Pb	Cu	Se	Zn
LDPE	<DL	<DL	<DL	<DL	<DL	1,15	<DL	6,73	<DL	<DL
N1	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	5,88
N2 ✖	<DL	<DL	0,751	<DL	<DL	<DL	<DL	1,24	<DL	**766**
M1	<DL	<DL	1,33	<DL	<DL	<DL	<DL	<DL	<DL	7,18
P1	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	10,5
M7 ✖	<DL	<DL	1,81	<DL	<DL	<DL	<DL	**581**	<DL	<DL
DL (mg/kg dm)	2,5	0,19	0,5	0,3	0,5	1	2	1	0,5	5
EN 13432 (mg/kg dm)	5	0,5	50	0,5	1	25	50	50	0,75	150

6. Laboratory plastics validation

Heavy metals content in plastic samples



Regulation (EC) No 1069/2009 and (EC) No1107/2009 relating to fertilisers

COM(2016) 157

Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009

- By including this innovative product in the **Fertilisers Regulation as soil improver** the EU could help tackle several challenges at once including the need to produce more food from less land and to farm more sustainably using less resources.
- According to the Commission, this proposal represents **a step forward towards a circular economy**. However, the proposal fails to recognise the potential role of biodegradable mulch films in modern agriculture *(Position of European Bioplastics & EuropaBio).*

Visual field assessment and soil analysis

Polymer characteristics

Microorganisms
Extracellular enzymes

Abiotic factors (Humidity, Oxygen, UV / vis irradiation)

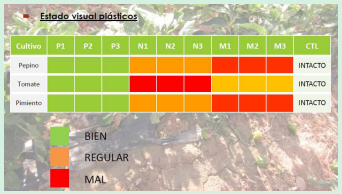
H_2O

CO_2

CH_4

Soil analysis

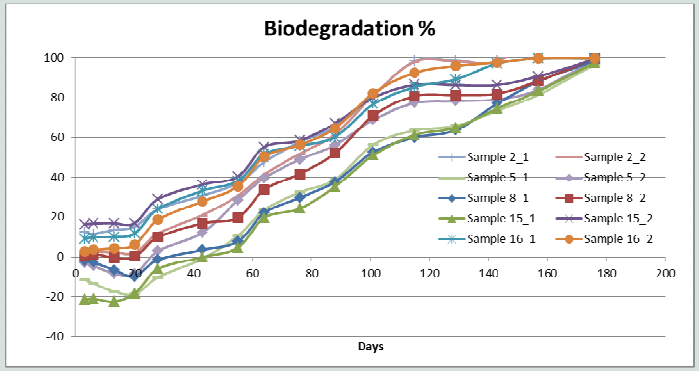
- Conductivity, pH
- Organic material, C / N
- Microelements and anions
- Weeds



Visual assessment

OK Soil Biodegradable

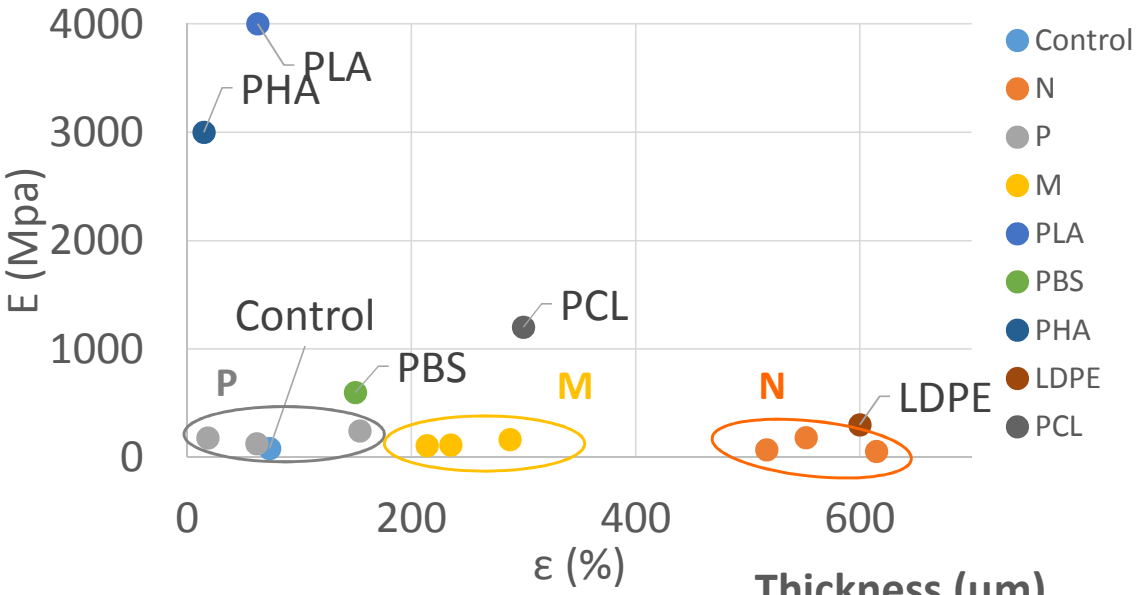
1. Heavy Metals
2. **Biodegradation: Plastic in soil samples (ASTM D5988)**

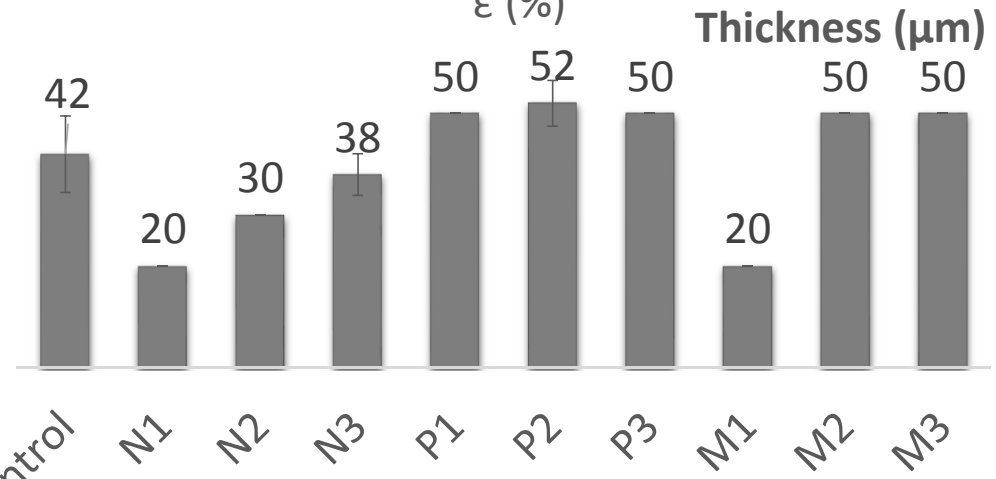


	Biodegradation (mean and standard deviation)			
	After 143 days		After 176 days	
N1	98,6	0,28	99,9	0,00
M1	79,6	3,54	99,2	0,85
P1	76,4	4,10	97,9	1,84
O2	80,55	8,27	98,5	1,27
O3	97,55	0,35	99,9	0,00

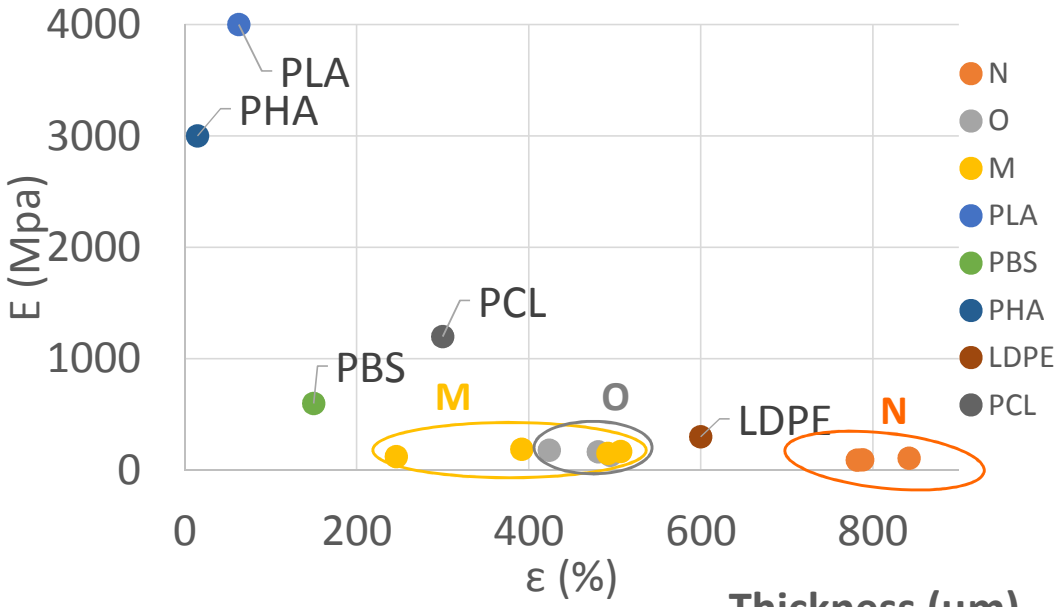
6. Laboratory plastics validation

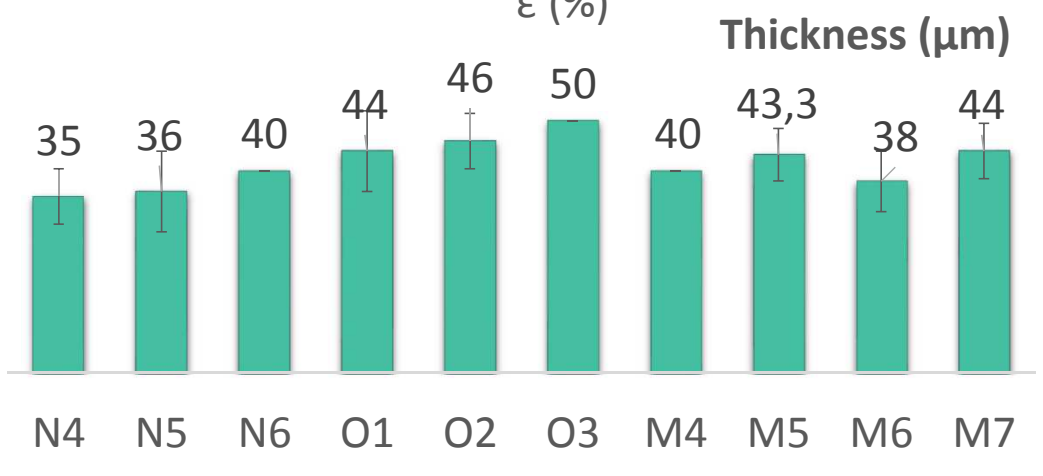
MULCHING





FRUIT BAGS



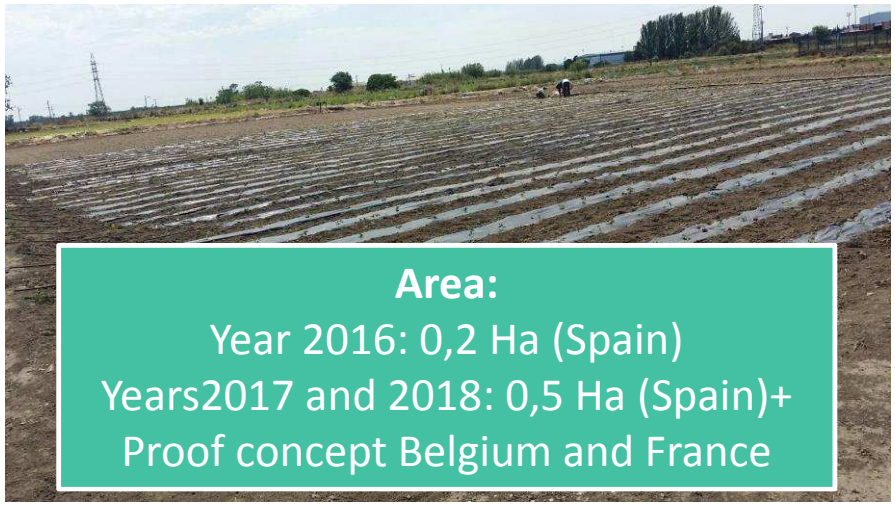


7. Validation of products in field

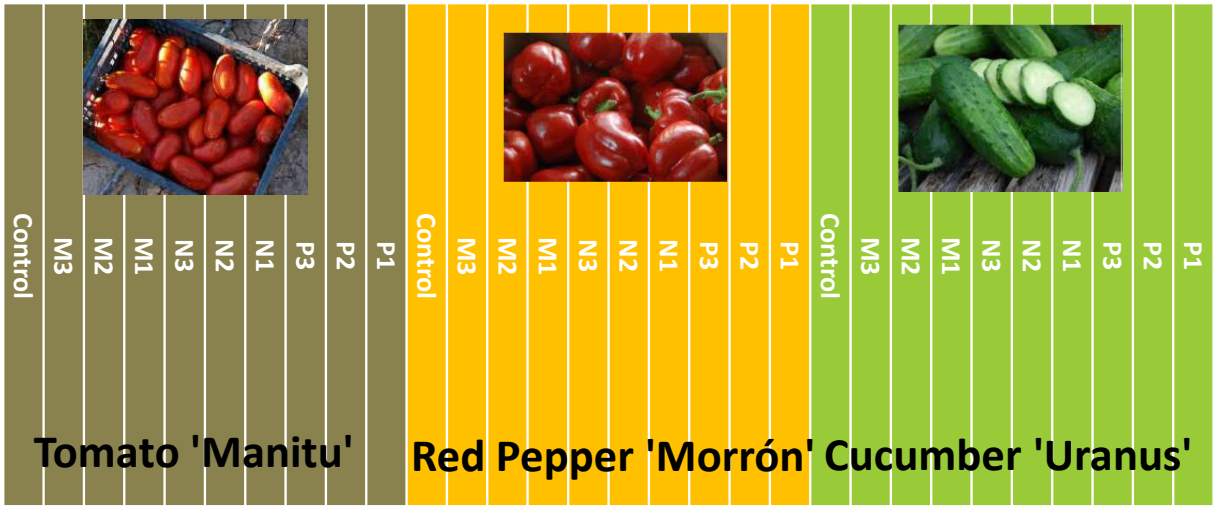
M1-M3: Sample based on PLA-PHA + MnZn (%)
N1-N3: Sample based on AAPE + MnZn (%)
P1-P3: Sample based on PBS + MnZn (%)

Product	Phase 1	Phase 2	Phase 3
Biomulching	**648 m²**	**2,664 m²**	2,016 m²
Biobags	900	3,700	2,800
Bioclips	900	3,700	2,800

- Lines 35 m
- 0,8 m with Drip irrigation
- Separation between plants: 0,5- 0,7 m
- Separation between lines: 1- 1,5 m
- Planting date: 24/05/2016
- Date of collection:
  - Tomato: 25/08/2016
  - Pepper: 13/10/2016
  - Cucumber: 07/07/2016



Area:
Year 2016: 0,2 Ha (Spain)
Years2017 and 2018: 0,5 Ha (Spain)+
Proof concept Belgium and France



7. Validation of products in field

M4-M7: Sample based on PLA-PHA + colour (%)
N4-N6: Sample based on AAPE + colour (%)
O1-O3: Sample based on AAPE + colour (%)

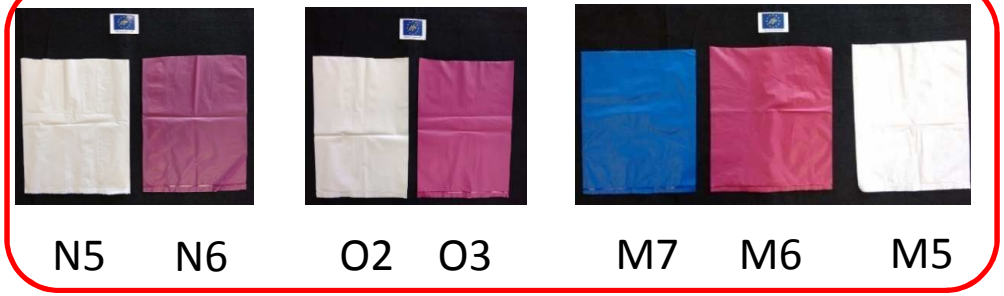
Product	Phase1	Phase2	Phase3
Biomulching	648 m^2	2,664 m^2	2,016 m^2
Biobags	**900**	**3,700**	2,800
Bioclips	900	3,700	2,800

September Peach

Fuji Apple

Peach field
1 ha
5×4 m
Drip irrigation

Apple field
1 ha
5×4 m
Drip irrigation

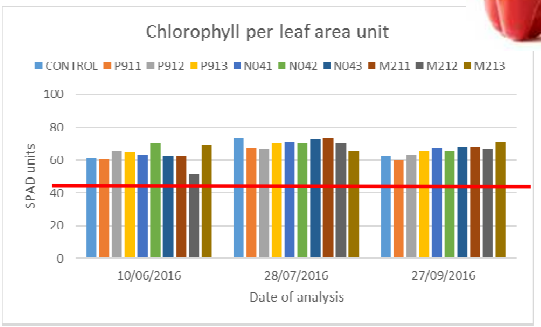


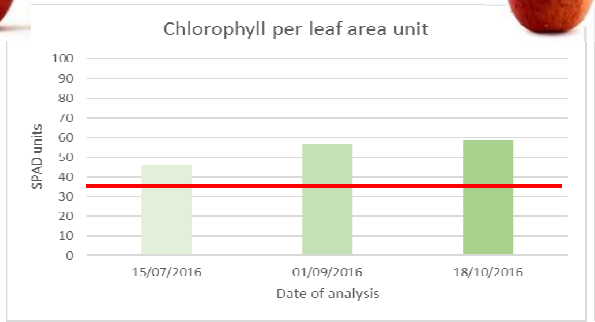
- ✓ Two months of bagging
- ✓ Biobags are easy to put at the tree

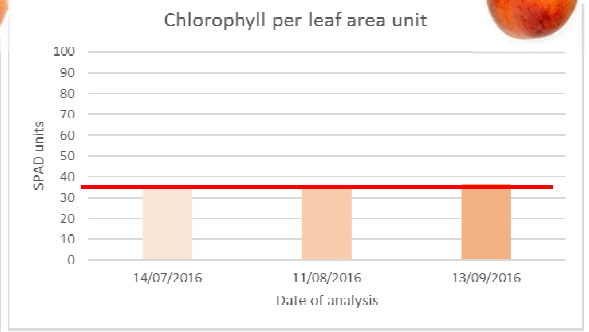
8. Preharvest quality measurements

The nutritional state of the crops was adequate throughout growing cycle.

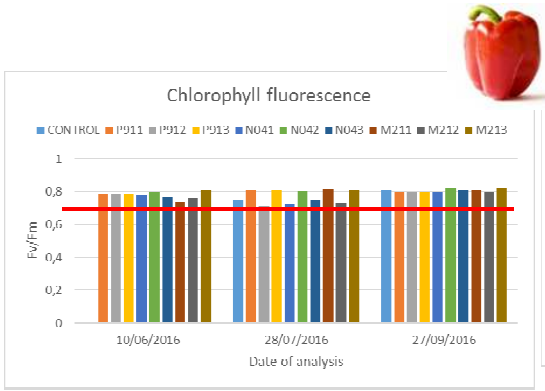
Chlorophyll per leaf area unit
Must be 40 units

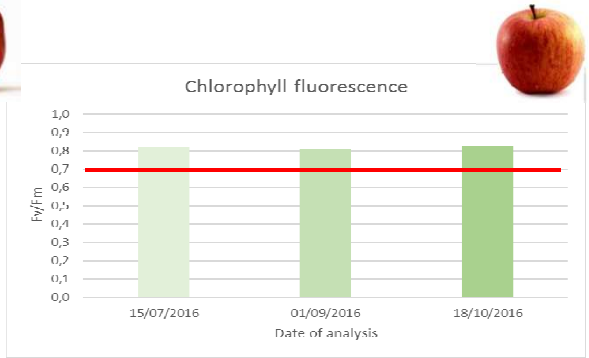


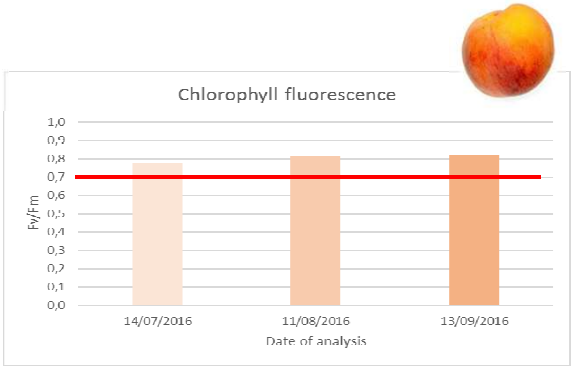




Chlorophyll fluorescence
Must be Fv/Fm = 0,7





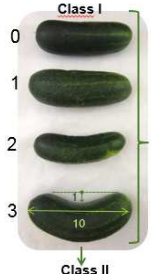


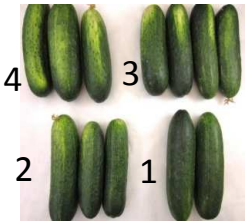
9. Post-harvest quality measurements

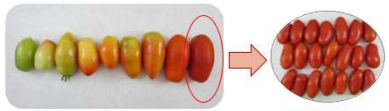
Classification → **Disorders and diseases** → **Quality analysis (Commercial class)**



Colour Caliber & weight





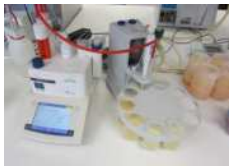



External damages



Internal damages






Acidity Soluble solids


Firmness


Sensory and olfactory analysis

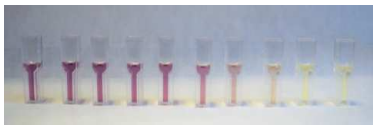
There were no differences in quality parameters between bioplastics and control.

- **150** VEGETABLES/BATCH and **75** FRUITS/BATCH were analysed (per year)
- Sample reduction: ***Early August HEATSTROKE September BLOSSOM END ROT and CALCIUM DEFICIENCY***
- Disorders and diseases were less than 1% with all bioplastics.

9. Post-harvest quality measurements

Nutritional compounds





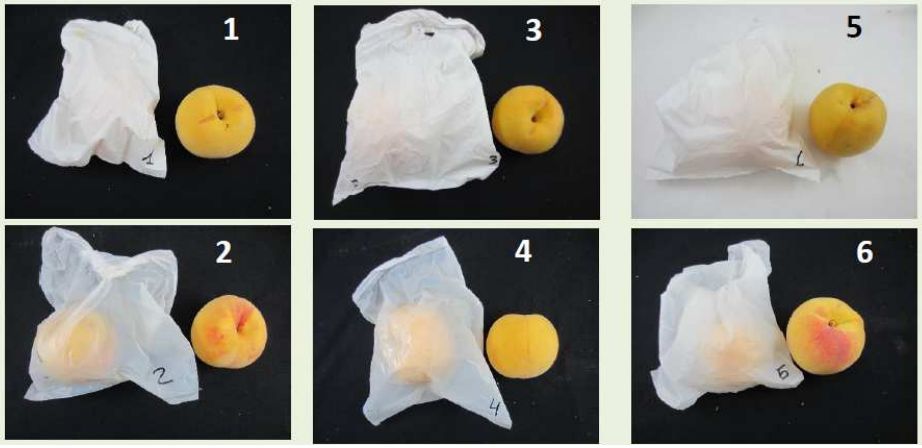
No significate differences were founded.

PRODUCT	NUTRITIONAL compounds
	Lycopene Vitamin C Polyphenols
	Vitamin C Polyphenols
	Chlorophyll Polyphenols

SAMPLE		PHENOLS (mg/100g)		Chla (µg/g)		Chlb (µg/g)	
material	additive	mean	s.d.	mean	s.d.	mean	s.d.
N	1	13,24	1,77	2,93	0,14	0,92	0,47
	2	12,11	1,69	3,04	0,61	1,13	0,32
	3	11,42	0,57	2,45	0,03	0,59	0,01
M	1	13,76	1,52	2,56	0,94	1,34	0,29
	2	12,76	0,28	2,98	0,60	1,52	0,25
	3	11,36	0,76	2,46	0,12	1,29	0,12
P	1	11,24	0,76	3,17	0,93	1,50	1,09
	2	10,79	2,20	4,30	0,51	1,56	0,40
	3	13,89	2,04	3,56	0,33	1,47	0,11
control	-	12,06	1,07	4,25	0,71	1,60	0,34
sign.		n.s.		n.s.		n.s.	

9. Post-harvest quality measurements

PEACH BAGS EFFECTS



The developed **biodegradable bags reduce** the amount of **reddish** colour in **peaches,** and at the same time, **maturity levels are the same or even higher** than those in control ones.

SAMPLE			ºBrix		a*	
nº	material	external	mean	s.d.	mean	d.s.
1	N	opaque	**14,58 c**	0,53	**14,49 ab**	1,68
2		translucent	**14,03 c**	0,25	**14,88 bc**	1,54
3	O	opaque	13,08 b	0,43	**13,16 a**	2,17
4		translucent	**14,70 c**	0,37	16,05 cd	1,67
5	M	opaque	12,35 a	0,62	**13,34 a**	1,79
6		translucent	12,93 ab	0,13	15,76 bcd	2,83
c	CONTROL	WP	12,78 ab	0,29	16,4 d	2,66
sign.			0,00		0,00	


control


M1


M4

- M samples have more rots and internal and external damages (34-52%).
- N and O biodegradable samples presents similar disorders and diseases (16-31%) than control (26%).

9. Post-harvest quality measurements

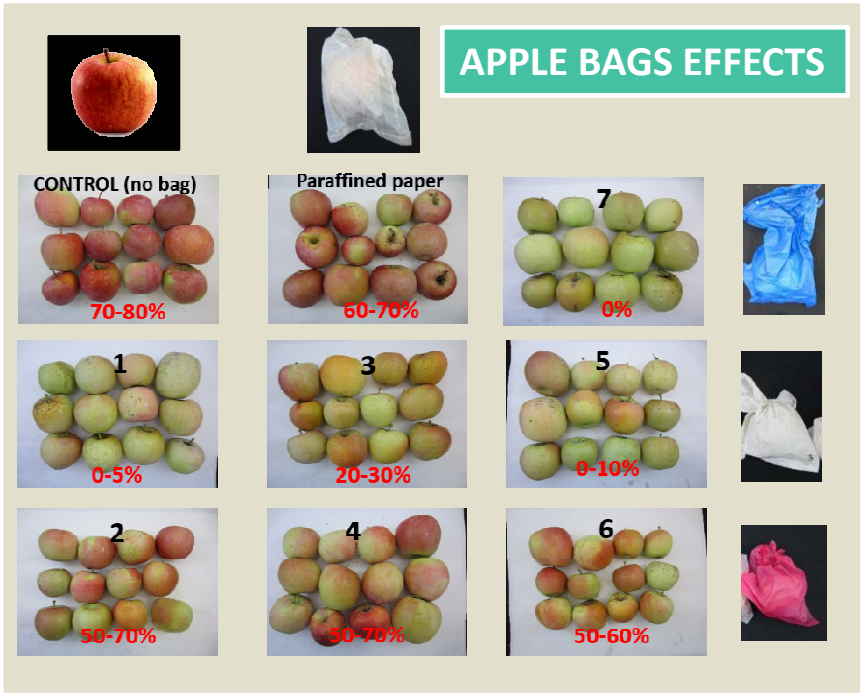
The developed **biodegradable bags** presents **higher polyphenols and carotenoids+xantophils** than control in **translucent bags** and **lower** in the opaque ones.

PEACH BAGS EFFECTS

SAMPLE			PHENOLS (mg/100g)		Xanthophyll +Carotenoids (µg/g)	
nº	material	external	mean	d.s.	mean	d.s.
1	N	opaque	46,62 ab	6,21	12,94 a	4,58
2		translucent	*53,63 b*	13,34	*19,87 ab*	4,55
3	O	opaque	31,36 a	11,52	16,51 ab	4,24
4		translucent	***58,43 b***	4,79	*22,41 b*	2,09
5	M	opaque	29,38 ab	6,83	13,52 a	0,14
6		translucent	***39,14 a***	11,95	*14,45 a*	2,79
c	CONTROL	WP	49,78 ab	14,53	14,30 a	4,56
sign.			0,029		0,048	

Nutritional compounds

9. Post-harvest quality measurements

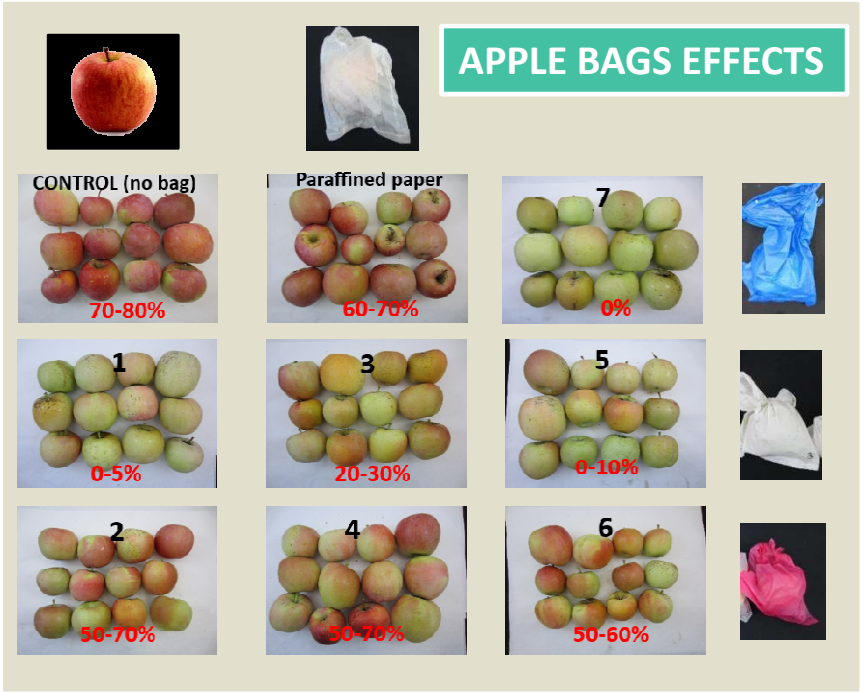


Biodegradable **red bags** allows to reach the **reddish** type of this variety while white and blue bags don´t.

SAMPLE			ºBrix		Coordinate a*	
nº	material	color	mean	s.d.	mean	s.d.
1	N	White	*16,23abc*	0,93	***0,67ab***	3,23
2		Red	***16,83bc***	0,75	***5,27cd***	5,17
3	O	White	*16,13abc*	1,42	***2,95bc***	2,88
4		Red	***17,37c***	0,81	***7,66de***	4,78
5	M	White	*16,47abc*	0,12	***-0,27a***	3,71
6		Red	*15,77abc*	1,24	***4,37c***	4,11
7		Blue	14,70a	1,23	***-2,12a***	2,17
P	WP	White	15,33ab	0,80	9,36e	5,81
C	CONTROL	no bag	14,83a	0,51	12,27f	5,09
	sign.		0,04		0,00	

Biodegradable samples presents similar disorders and diseases (24-42%) than waxed paper (37%) but both are higher than without bag (6% red points no rots).

9. Post-harvest quality measurements



Biodegradable **red bags** allows to reach similar Antocians content than waxed paper or without bag while white and blue bags don´t.

SAMPLE			ANTOCIANS (mg eq C3Glucosido/100g)	
nº	material	color	mean	s.d.
1	N	White	***4,59 b***	*0,50*
2		Red	***6,9 c***	*0,39*
3	O	White	***4,43 b***	*0,25*
4		Red	***6,97 c***	*0,31*
5	M	White	***4,75 b***	*0,25*
6		Red	***6,74 c***	*0,30*
7		Blue	***1,41 a***	*0,25*
P	WP	White	*8,58 d*	*0,26*
C	CONTROL	no bag	*8,66 d*	*0,31*
	sign.		0,025	

Nutritional compounds

9. Post-harvest quality measurements

Reduction of number of pesticides treatments following the completion of bagging technique in the **peach crop.** **That means a reduction of a 50% in pesticide treatments.**

Ceratitis capitata

Grafolita molesta / Anarsia lineatella

PLAGUE/Nº TREATMENTS	BAG LESS	BAGGED
G. MOLESTA Y A. LINEATA	8	4
C. CAPITATA	6	2
TOTAL	14 (12)	6

Pesticide Residues

In the analysis of **pesticide residues**, some traces of **Difenoconazole** (lower MRL) have been detected in apples grown **without bags**, with **waxed paper** bags and with biodegradable plastic O2 and O3. It is worth noting the **absence of pesticide residues** in apples covered with **N** and **M** bioplastics.

MRL: 0,8

Batch	Colour	Sample	Pesticide
1	**White**	N5	NO
2	**Red**	N6	NO
3	**White**	O2	**0,011**
4	**Red**	O3	**0,012**
5	**White**	M5	NO
6	**Red**	M6	NO
7	**Blue**	M7	NO
Control bag	**WP (White)**		**0,011**
CONTROL	**no bag**		**0,012**

10. Economic Analyses

- We have probed that **performance** of biodegradable mulch is **comparable** to conventional mulch.
- That are **biodegradable on soil**, in application were this facts **adds value** to the solution.
- **But**… we need the support of **policies and reduction of costs**…

-30%

RD 533/2017, of May 26, which regulates the funds and operational programs of organizations of producers of fruit and vegetables.

Thickness	Kg/ha (Bio)***	PRICE PE *,**(2€/kg)	PRICE BIO (4,5€/kg) +oligo elements (X%)	PRICE (BIO)Mulching + -30%	DIFERENCE
15	189	465 €/ha	852 €/ha	596 €/ha	131 €/ha
30	378	735 €/ha	1700 €/ha	1193 €/ha	458 €/ha
50	630	1105 €/ha	2840 €/ha	1988 €/ha	883 €/ha

*Costs of removal and disposal are included **(between 200 and 400 €/ha according to the country legal requirements).** *The cost **in Belgium** of mechanical cleaning (120 €) and removal and disposal (55 €) in total 175 €.*

Costs of oligoelements **20 €/ ha (average 3 Kg/ha)

*** ρ (PE) = 0,9 g/cm^3 & ρ (bio) = 1,26 g/cm^3

10. Economic Analyses

- We have probed that **performance** of biodegradable fruit bags are **comparable** to standard bags.
- That are **biodegradable on soil**, in application were this facts **adds value** to the solution.
- **But**… we need the support of **policies and reduction of costs**…

-30%

RD 533/2017, of May 26, which regulates the funds and operational programs of organizations of producers of fruit and vegetables.

FRUIT BAGGING: Currently, it has been trying to **close this cost-benefit gap (€ 2,901.64) through CAP European aids** for farmers who are enrolled in organizations of fruit and vegetables producers.

Waxed paper **0,0075 €/bag** -30% Biodegradable 0,0003 €/bag → **0,000193 €/bag**

ITEM		€/Ha
specific costs increment	*Fruit thinning*	*€ 216.00*
	Fruit bagging	*€ 3,517.50*
	Harvest	*€ 648.00*
	Bag handling and disposal	*€ 316.80*
	TOTAL specific costs increment	**€ 4,698.30**
benefits of using the technique	***Pests treatments reduction***	***€ 490,36***
	Peach price increment due to the peach bagging	***€ 1,306.30***
	TOTAL benefits of bagging technique	**€ 1,796.66**
Difference cost-benefit (per ha.)		**€ 2,901.64**

11. Conclusions

- New formulations for Biomulching have been developed.
  - ✓ Certain % Zn/Mn can be added in the mulching providing an innovative characteristic.
  - ✓ Reduction of plastic waste has been achieved (98-99,9% biodegradation in 176 days).
  - ✓ Mechanical properties of bioplastics are similar to those of LDPE.
  - ✓ Plant health were adequate during assays of 3 months.
  - ✓ Crop quality and nutritional content were similar to the obtained with conventional mulching.
  - ✓ Lower thickness make plastics breakable in fields
  - ✓ Costs need to be reduced to be competitive.

- New formulations for Biobags have been developed.
  - ✓ Reduction of plastic waste will be achieved (98,5 -99,9% biodegradation in 176 days).
  - ✓ Reduction of pesticides treatments -> better crop quality.
  - ✓ Mechanical properties of bioplastics are similar to those of LDPE.
  - ✓ Colour can be used providing an innovative characteristic: Affects to fruit coloration but not to maturation.
  - ✓ Macroperforations eliminate water inside bags, producing similar rots than with other type of bagging.
  - ✓ Translucent white bags presents higher nutritional compounds than opaque and control ones.
  - ✓ Biobags price can be competitive with conventional ones (waxed paper).

Agricultural Film 2017

Innovative fully biodegradable mulching films and fruit protection bags for sustainable agricultural practices

Multibiosol

Project co-financed by the European Union through the LIFE Programme
LIFE14/ENV/ES/486
Sep. 2015 – Dic. 2018
http://multibiosol.eu/

Thank you for your attention

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