

Agricultural Film

2017



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

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ExxonMobil

Media supporter:

Film and Sheet
EXTRUSION

Agricultural film 2017

Barcelona, 26-28 September 2017


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1. Our organization

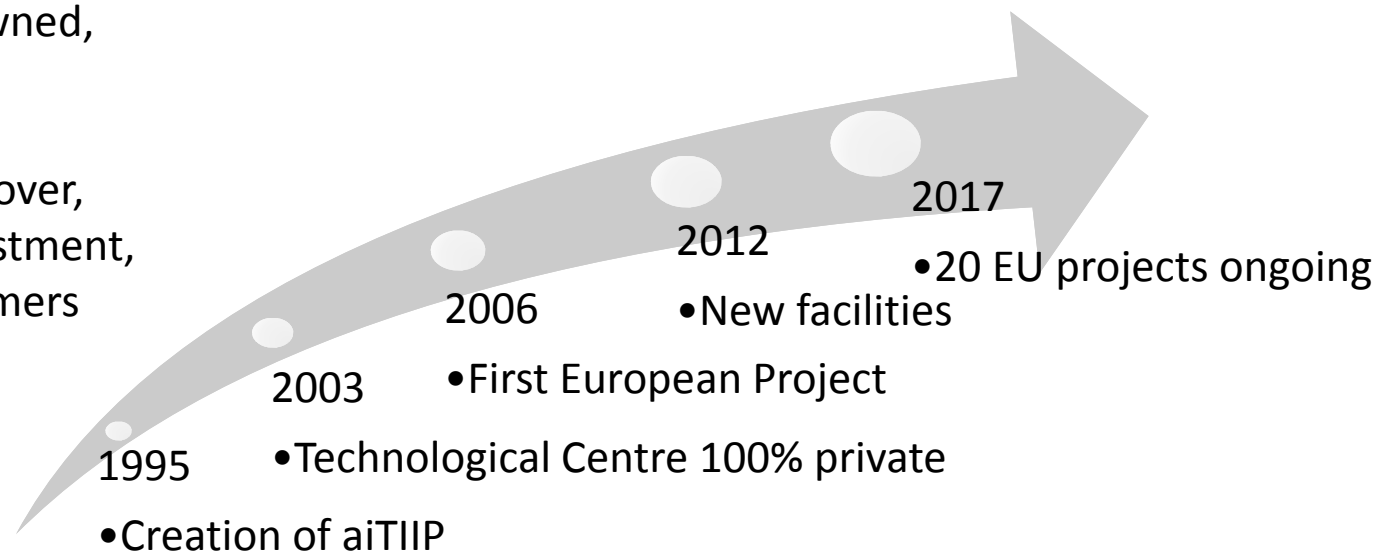


Key Activities

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  (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

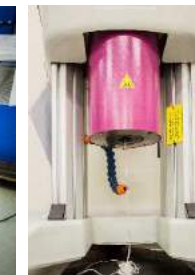
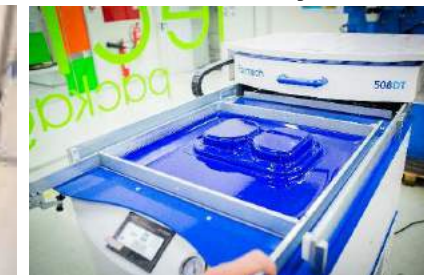
Main Sectors

Automotive
Aeronautic
Agroindustry
& Food
Packaging

For more information please visit: www.aitiip.com



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



Agricultural film 2017

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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:

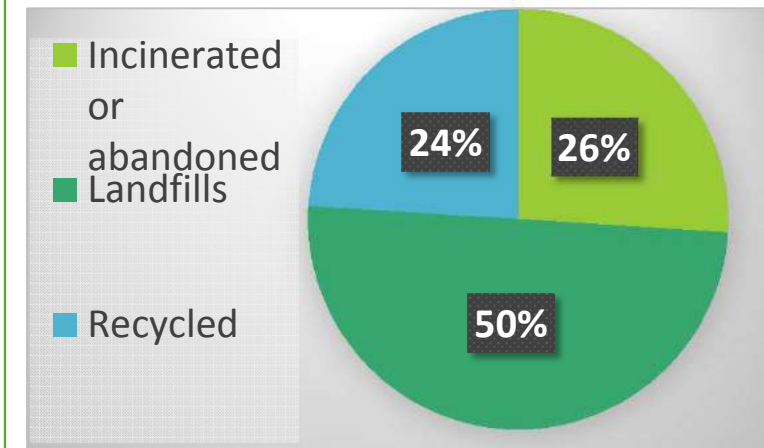
- Single use only
- Elimination involves high costs in terms of time and money



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...

CONSUMPTION OF AGRICULTURAL FILM IN EUROPE



2. Purpose of this line of investigation

Agroplastics are needed:

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



Innovations

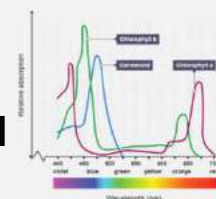


Sustainable



Trace elements

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



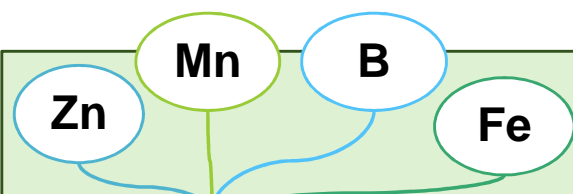
Macro-perforations
Coloring bags



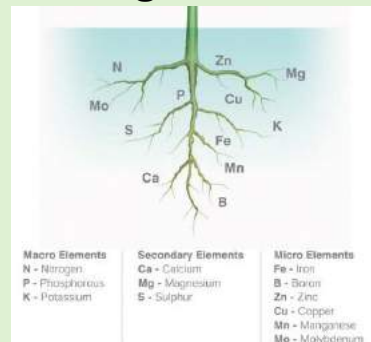
Protected Designation Origin

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

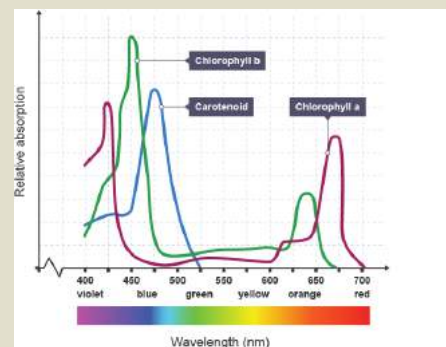


- **Iron** deficiency is the main lack in crops under plastic (chlorosis)
- **Boron** deficiency appears in dry climates (important for plant metabolism)
 - **Zinc** is required by many enzymes (hormone auxin, little leaf)
- **Manganese** is necessary for photosynthesis (coloration)

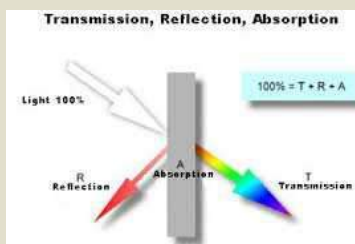
↓ Plastic Legislation

Fertilizer value ↑

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)

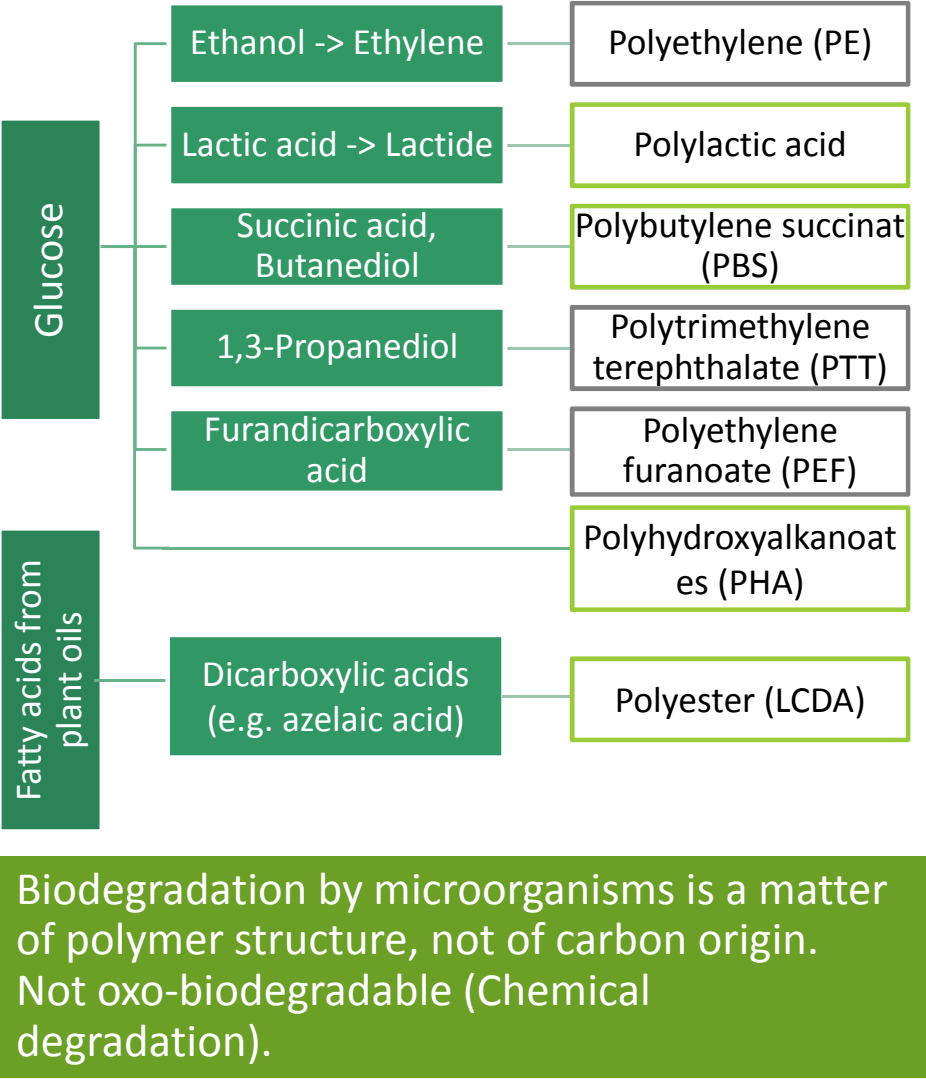
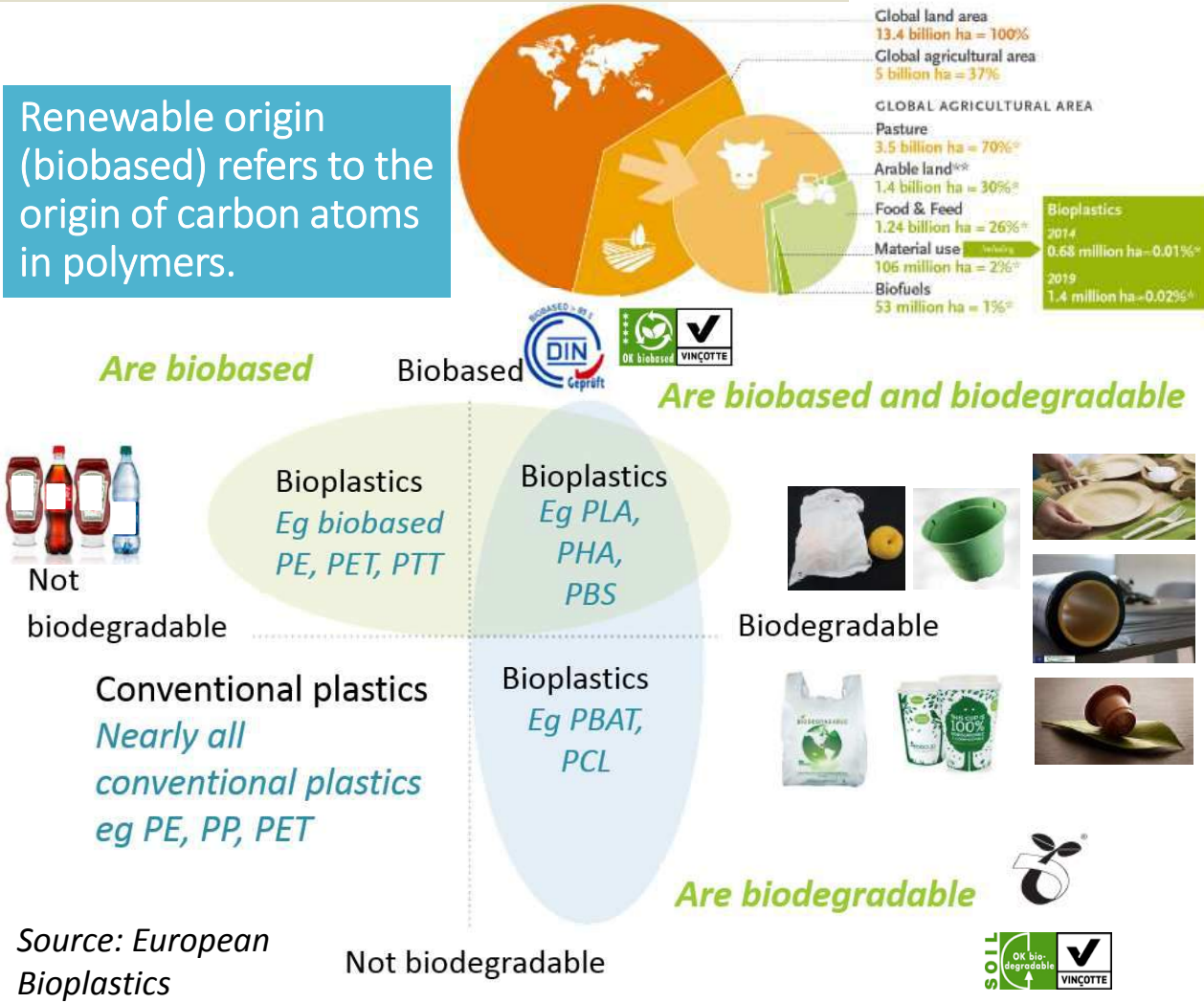
Expected results

- Reduction of plastic waste
- Less CO₂ 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.



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)

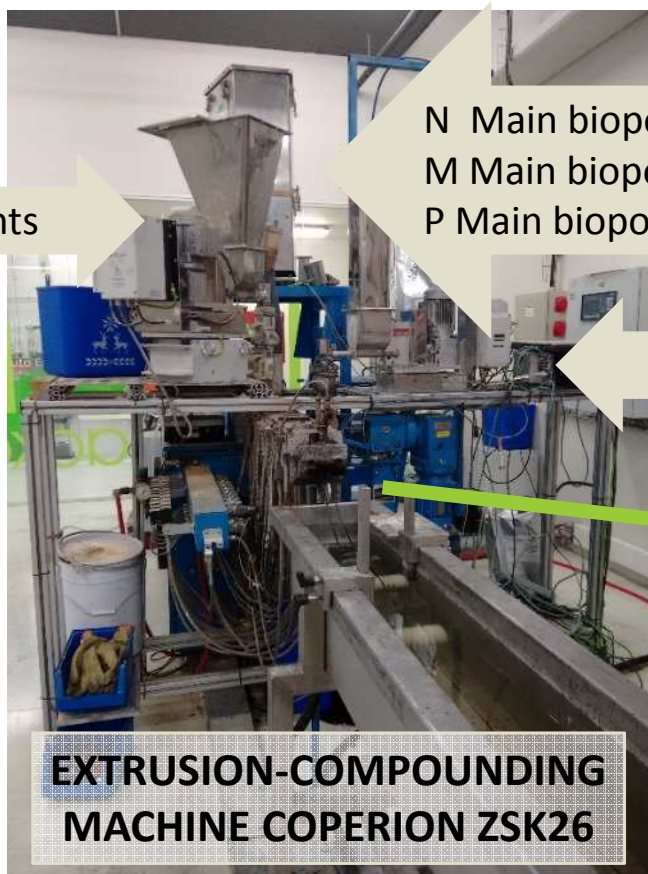
- Pelletizer and dryer on the same line.
- Adapted screws for several materials and additives
- Ultrasonic system of dispersion available



Oligo elements



- ✓ T^a control
- ✓ Material flow control
- ✓ % components



**EXTRUSION-COMPOUNDING
MACHINE COPERION ZSK26**

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



Carbon Black



**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

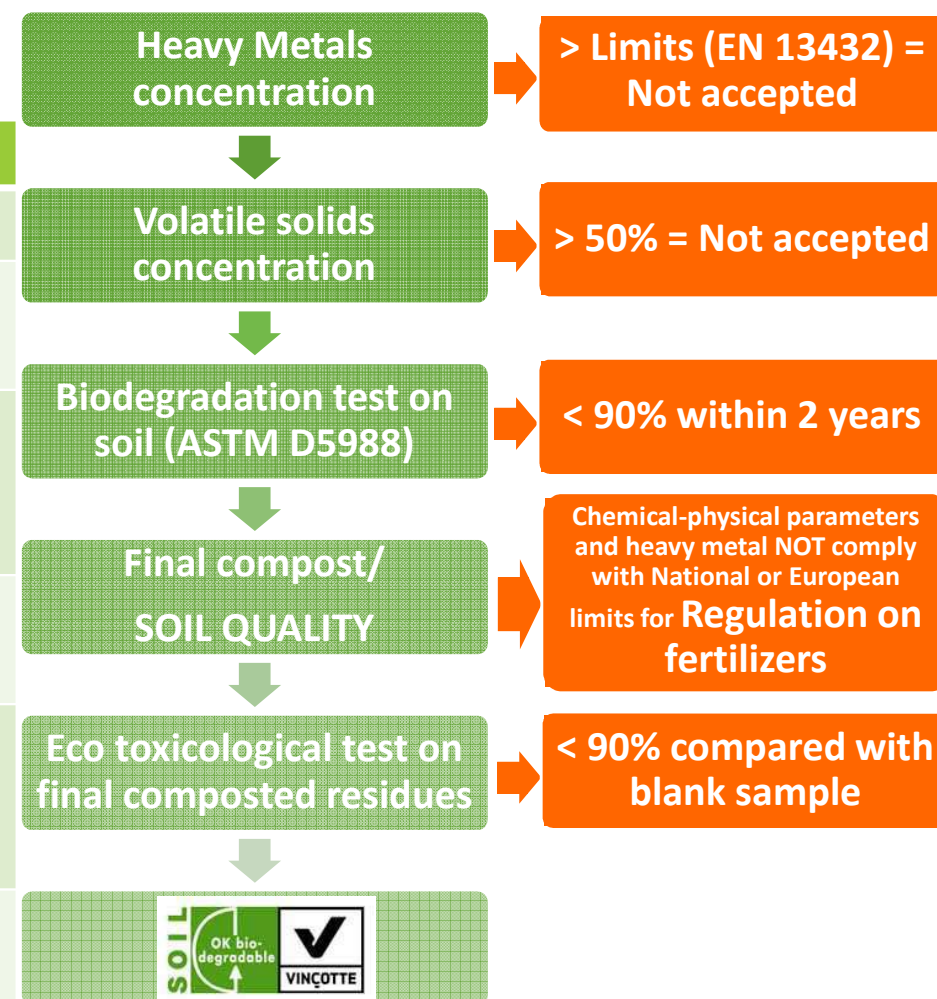


Film for fruit bags

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
<u>Tensile Properties</u> of Thin Plastic Sheeting	ASTM D 882 – 12
<u>Tear-Propagation Resistance</u> of Plastic Film and Thin Sheeting by a Single-Tear Method	ASTM D 1938 –14
<u>Flexural Properties</u> 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
<u>Water Vapor Transmission Rate</u> Through Plastic Film and Sheeting Using a Modulated Infrared Sensor	ASTM F1249 - 13
<i>“OK Biodegradable Soil”</i>	EN13432:2000



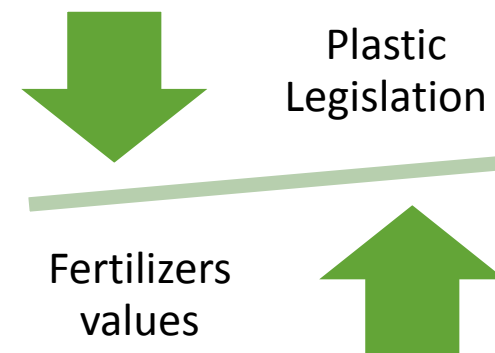
6. Laboratory plastics validation

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

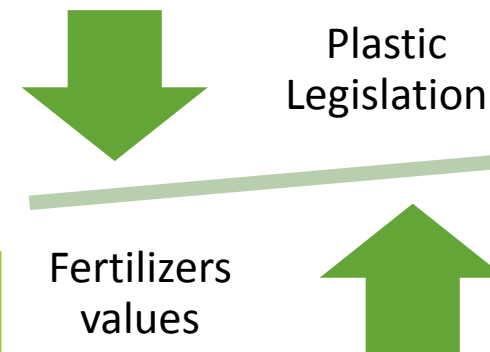
6. Laboratory plastics validation

Heavy metals content in plastic samples

Regulation (EC) No 1069/2009 and (EC) No 1107/2009 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)

H₂O

CO₂

CH₄

Soil analysis

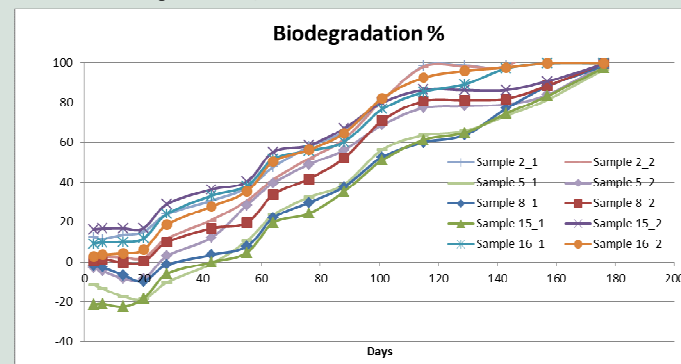
- Conductivity, pH
- Organic material, C / N
- Microelements and anions
- Weeds

Visual assessment



OK Soil Biodegradable

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



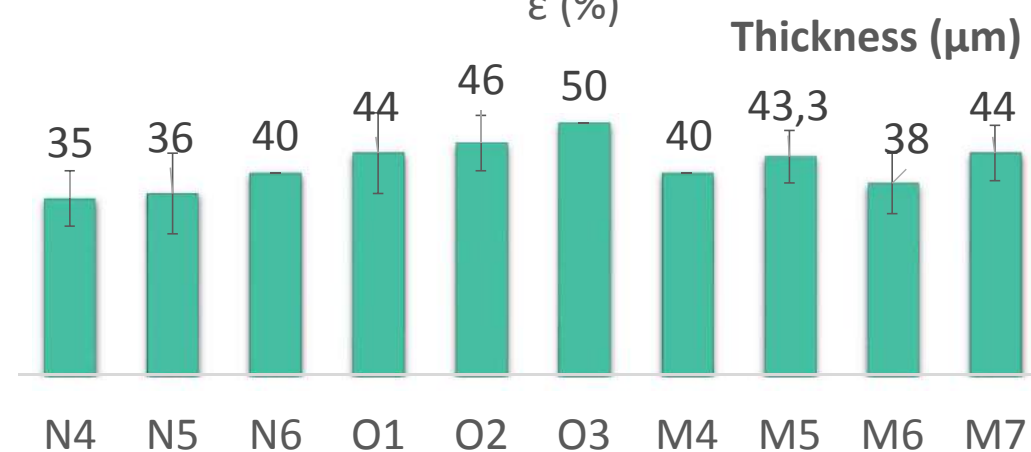
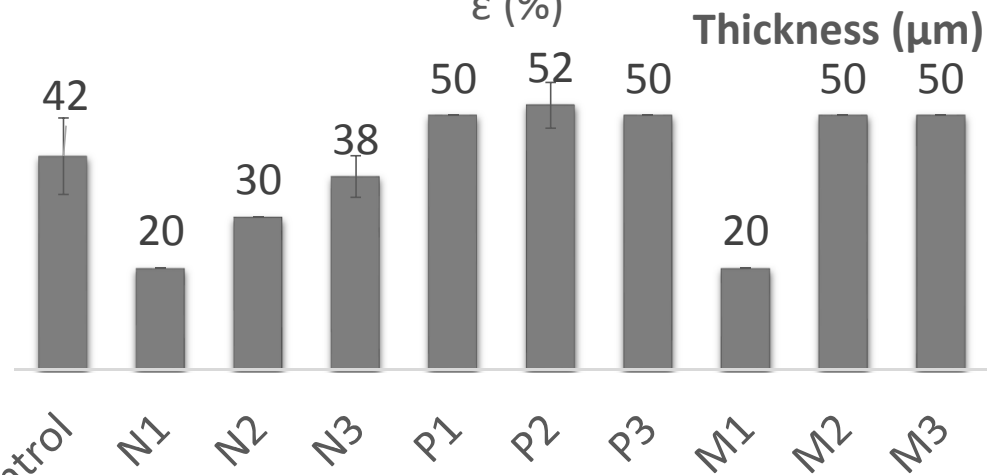
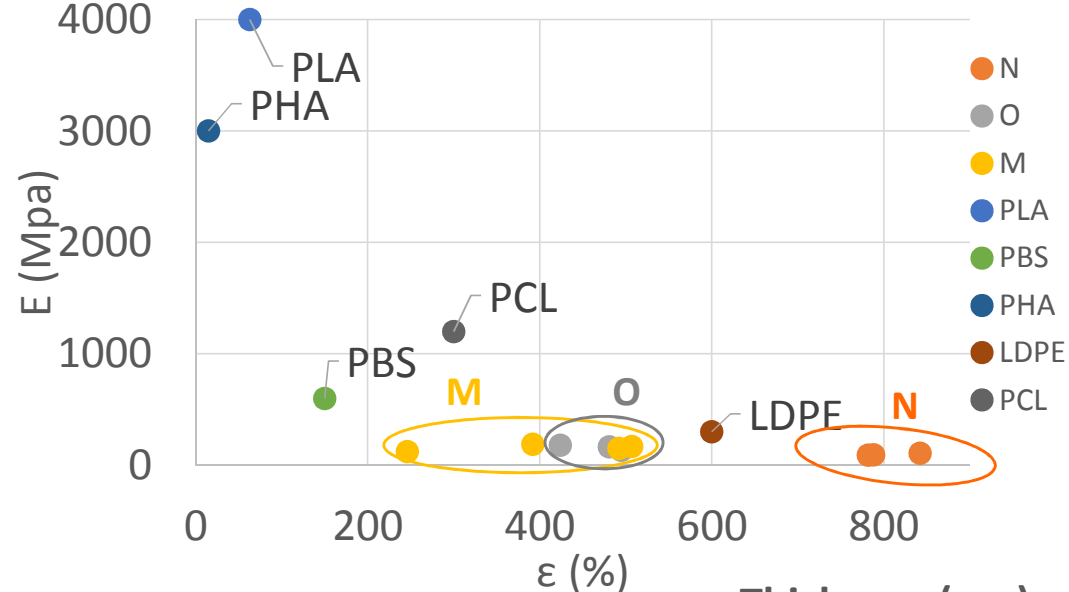
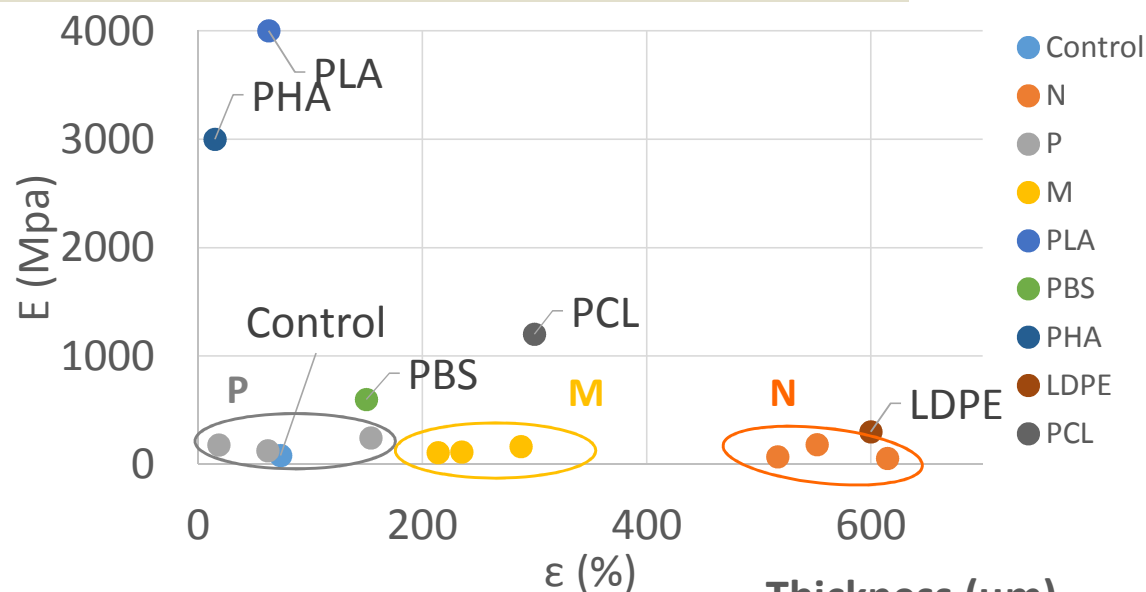
Biodegradation (mean and standard deviation)

	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

MULCHING

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 m ²
Biobags	900	3,700	2,800
Bioclips	900	3,700	2,800



Area:

Year 2016: 0,2 Ha (Spain)
Years 2017 and 2018: 0,5 Ha (Spain)+
Proof concept Belgium and France

- 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:



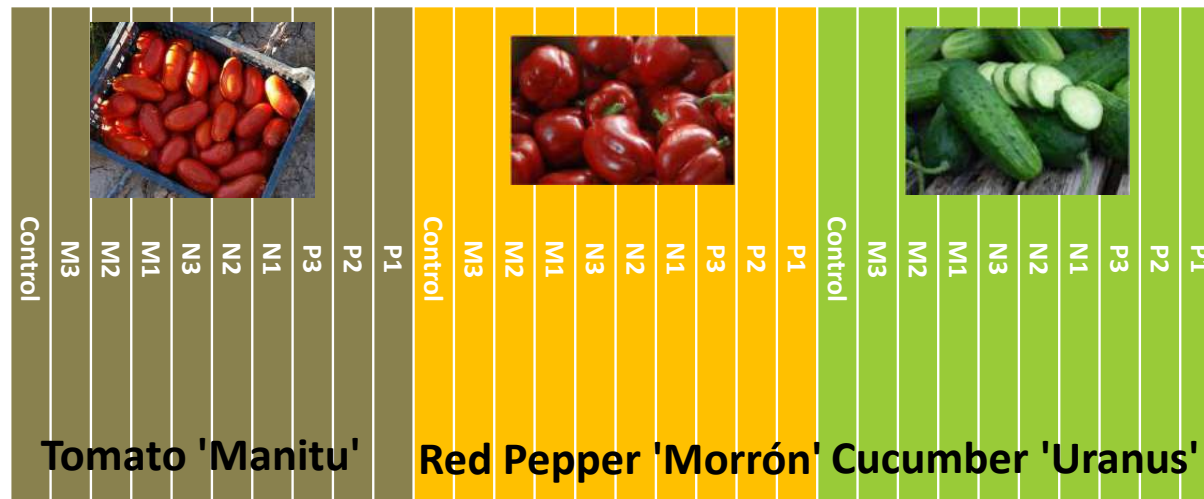
Tomato: 25/08/2016



Pepper: 13/10/2016



Cucumber: 07/07/2016



7. Validation of products in field



BAGS

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
 5x4 m
 Drip irrigation



Apple field

1 ha
 5x4 m
 Drip irrigation



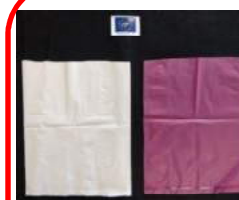
N4 N5



O1 O2



M4 M5



N5 N6



O2 O3



M7 M6 M5

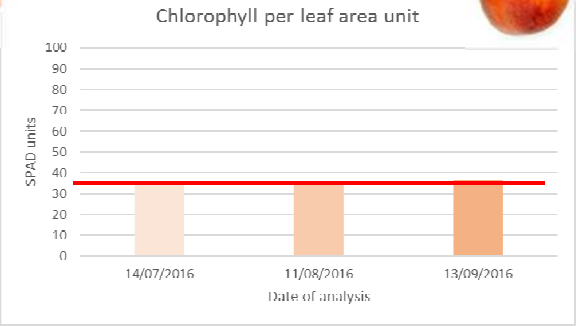
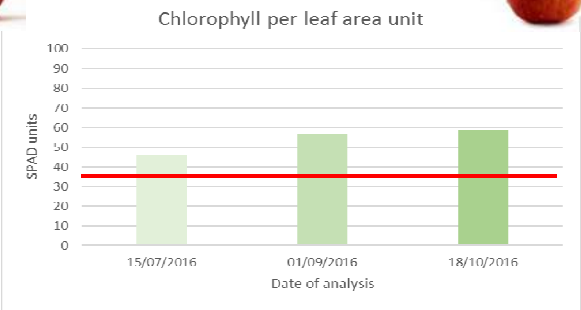
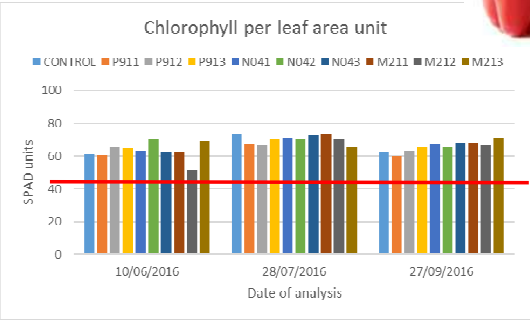
- ✓ Two months of bagging
- ✓ Biobags are easy to put at the tree

8. Preharvest quality measurements

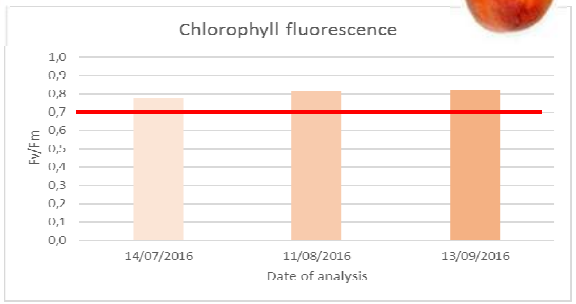
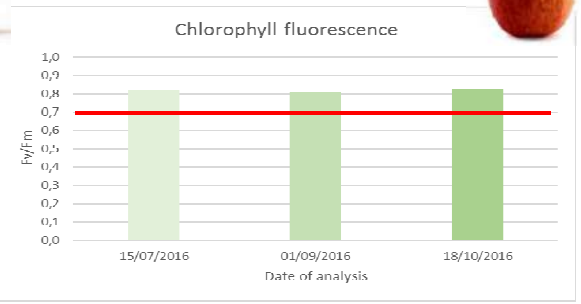
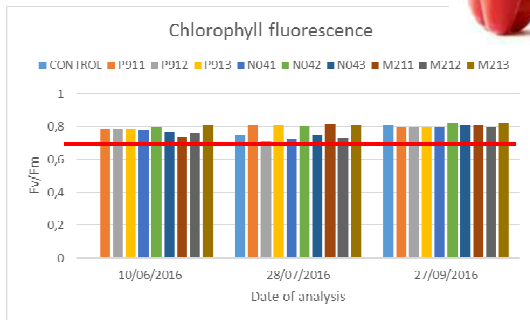
The nutritional state of the crops was adequate throughout growing cycle.



**Chlorophyll per leaf area unit
Must be 40 units**



**Chlorophyll fluorescence
Must be $F_v/F_m = 0,7$**



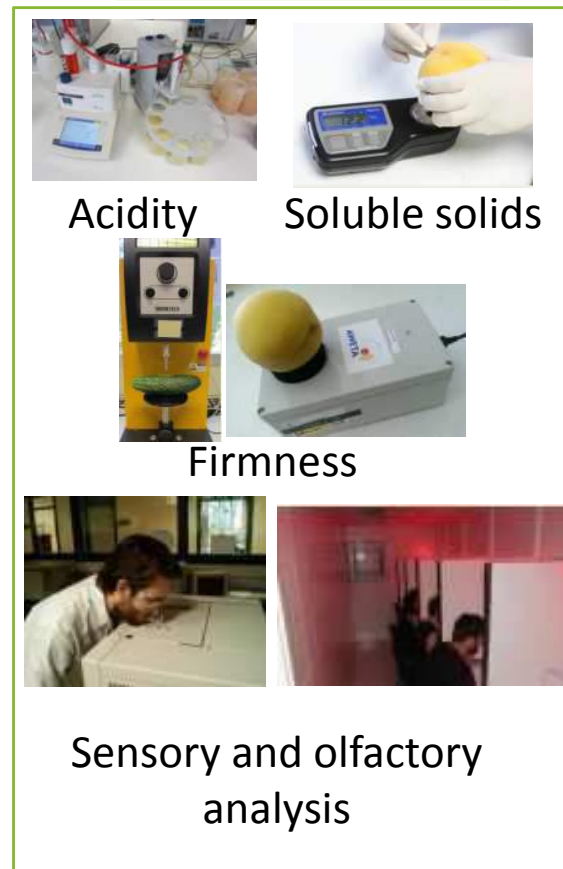
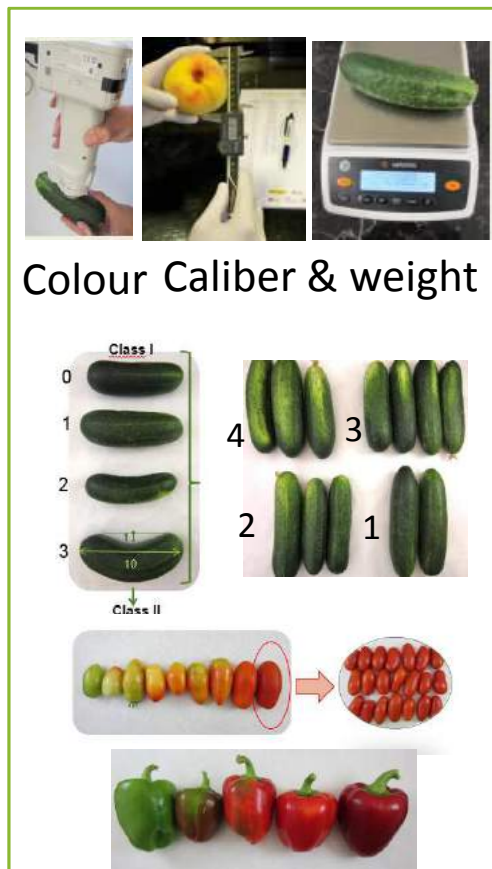
9. Post-harvest quality measurements

Classification

Disorders and diseases

Quality analysis (Commercial class)

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 significant
differences were
found.

PRODUCT

NUTRITIONAL
compounds



Lycopene
Vitamin C
Polyphenols



Vitamin C
Polyphenols

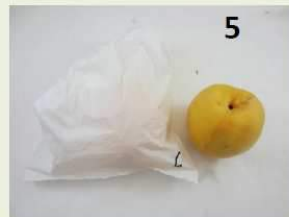


Chlorophyll
Polyphenols

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



control



M1



M4

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.

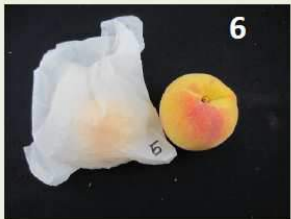
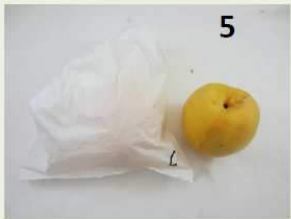
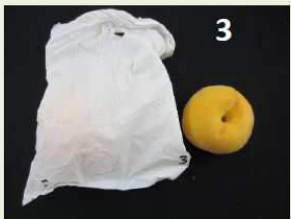
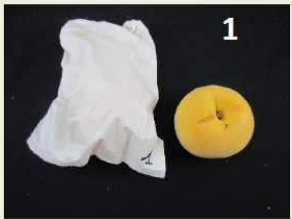
SAMPLE			°Brix		a*	
nº	material	external	mean	s.d.	mean	d.s.
1	N	opaque	14,58 c	0,53	14,49 ab	1,68
2		translucent	14,03 c	0,25	14,88 bc	1,54
3	O	opaque	13,08 b	0,43	13,16 a	2,17
4		translucent	14,70 c	0,37	16,05 cd	1,67
5	M	opaque	12,35 a	0,62	13,34 a	1,79
6		translucent	12,93 ab	0,13	15,76 bcd	2,83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



- 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

PEACH BAGS EFFECTS



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

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

APPLE BAGS EFFECTS

CONTROL (no bag)

70-80%

Paraffined paper

60-70%

7

0%

1

0-5%

3

20-30%

5

0-10%

2

50-70%

4

50-70%

6

50-60%



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).

Biodegradable **red bags** allows to reach the **reddish** type of this variety while white and blue bags don't.

SAMPLE			°Brix		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	

9. Post-harvest quality measurements

CONTROL (no bag)

70-80%

Paraffined paper

60-70%

APPLE BAGS EFFECTS

7

0%

1

0-5%

3

20-30%

5

0-10%

2

50-70%

4

50-70%

6

50-60%

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.



Ceratitidis 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/cm³ & ρ (bio) = 1,26 g/cm³

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	<i>Fruit thinning</i>	€ 216.00
	<i>Fruit bagging</i>	€ 3,517.50
	<i>Harvest</i>	€ 648.00
	<i>Bag handling and disposal</i>	€ 316.80
	TOTAL specific costs increment	€ 4,698.30
benefits of using the technique	<i>Pests treatments reduction</i>	€ 490,36
	<i>Peach price increment due to the peach bagging</i>	€ 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



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<http://multibiosol.eu/>



Thank you for your attention

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