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Biodegradable plastics for improving soil and fruit quality characteristics

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[3]Laboratori ARCHA, Pisa, Italy; [4] Parque Científico Tecnológico Aula Dei, Zaragoza, Spain.

Multibiosol Life +

Project co-financed by the European Union through the LIFE Programme

Agriculture, Plastics & Environment

XXIst CIPA CONGRESS

Bordeaux – Arcachon - France

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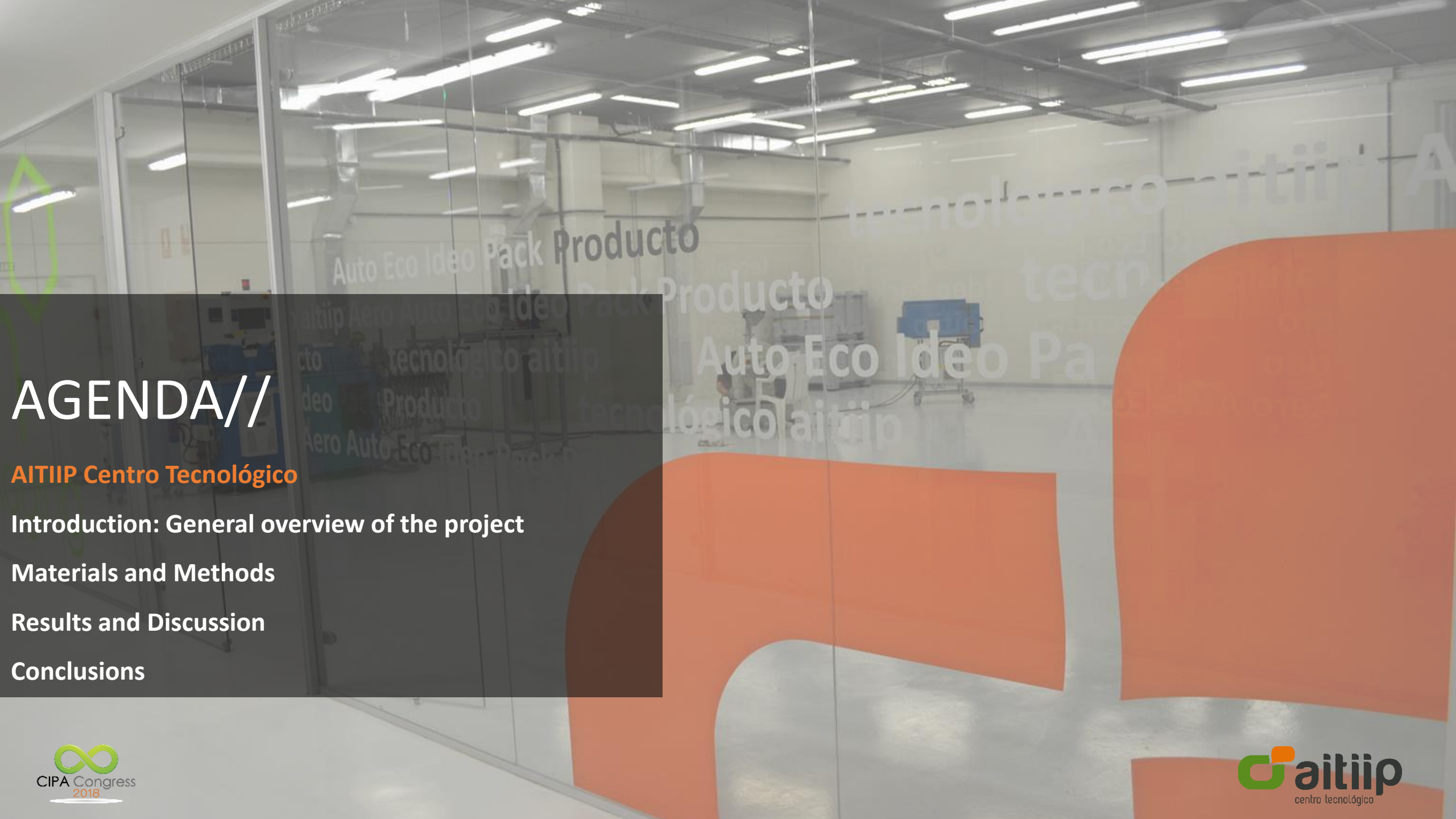

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AITIIP Centro Tecnológico

Introduction: General overview of the project

Materials and Methods

Results and Discussion

Conclusions

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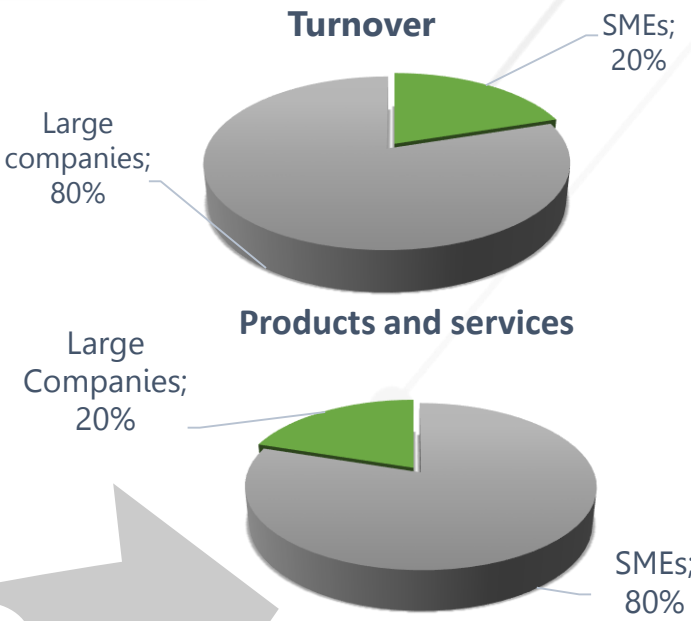
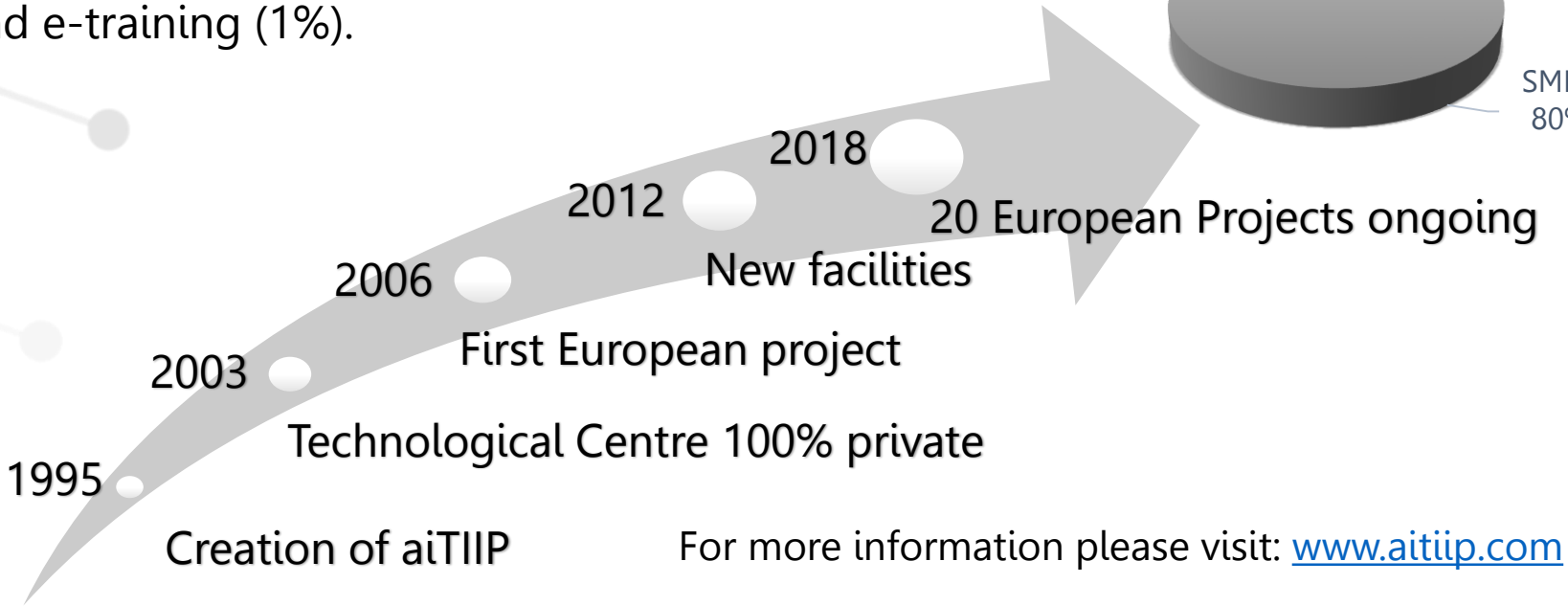
- AITIIP is a private technological centre whose goal is to increase the competitiveness of companies in the industry of moulds and plastic parts manufacturing.
- AITIIP offers advanced technology services to other companies (62% of the income), performs research, development and innovative actions (37%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



Key Figures (2017)

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



For more information please visit: www.aitiip.com

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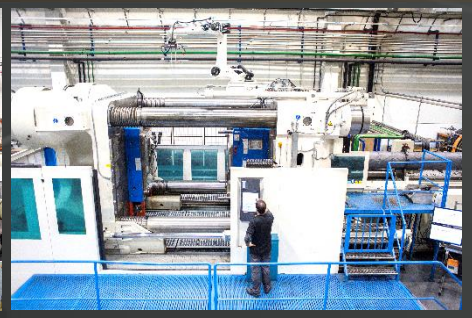
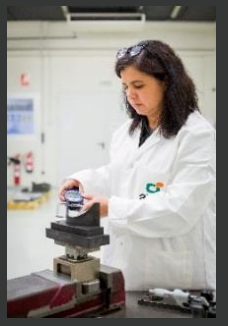
Plastic Injection

High quality machining and finishing



3D Printing

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



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European Projects

circpack · MEGA TROB * · KRAKEN * · BARBARA * · fungus chain · HyperBioCoat · ECOxy · WIN TOOL * · FALCON * · cardemy * · DELTA DRONES · bioplastictrain * · Multibiosol * · CITRUS PACK * · Freshbox · CE PLAFIB

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

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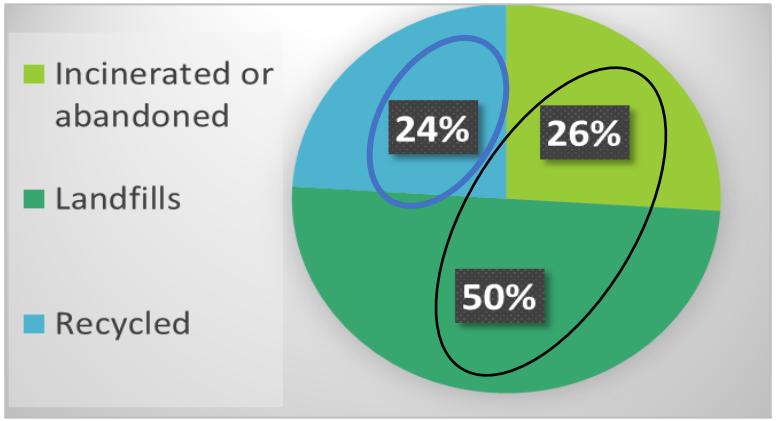
General overview of the project

Production

Consumption

End of life



They are used mainly in Italy, France, Germany, Benelux and Spain.

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General overview of the project

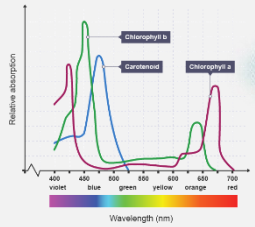
Agroplastics are needed: *Innovations* *Sustainability*

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

Trace elements

Protected Designation Origin

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



Macro-perforations
Coloring bags

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.

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General overview of the project

Mulching Innovations

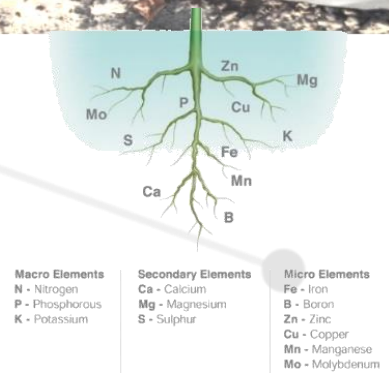
Zn

B

Mn

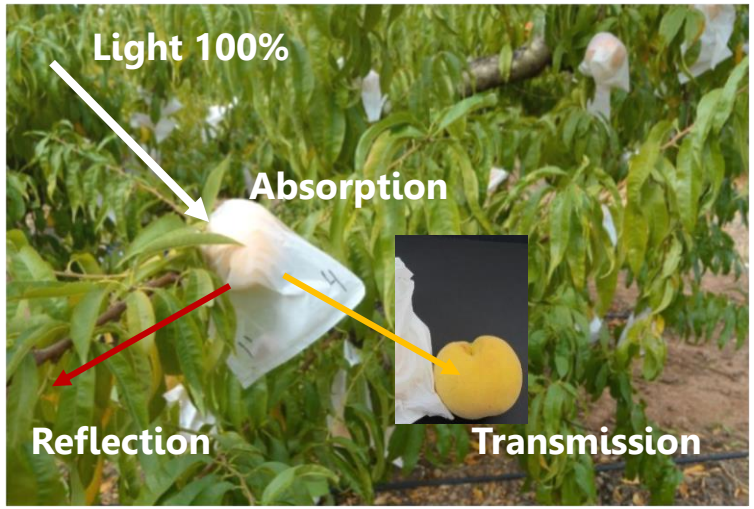
Plastic Legislation

Fertilizer value

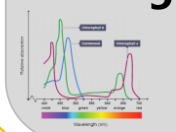


- **Boron** deficiency appears in dry climates (important for plant metabolism)
- **Zinc** is required by many enzymes (hormone auxin, little leaf)
- **Manganese** is necessary for photosynthesis (coloration)

Fruit protection bags innovations



- **Macro perforations** to prevent rotting due to the concentration of water vapour.
- **Pigment Skin Active Radiation** capable of producing colour surface fruit.



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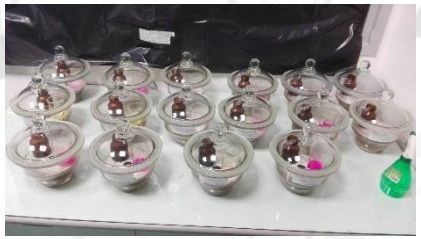
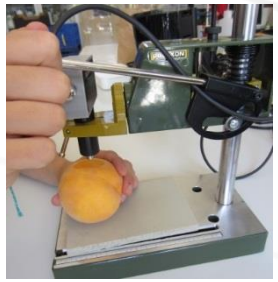
General overview of the project





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

Production processes
-Materials extrusion
-Film blowing

Demonstration Character

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)

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)

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

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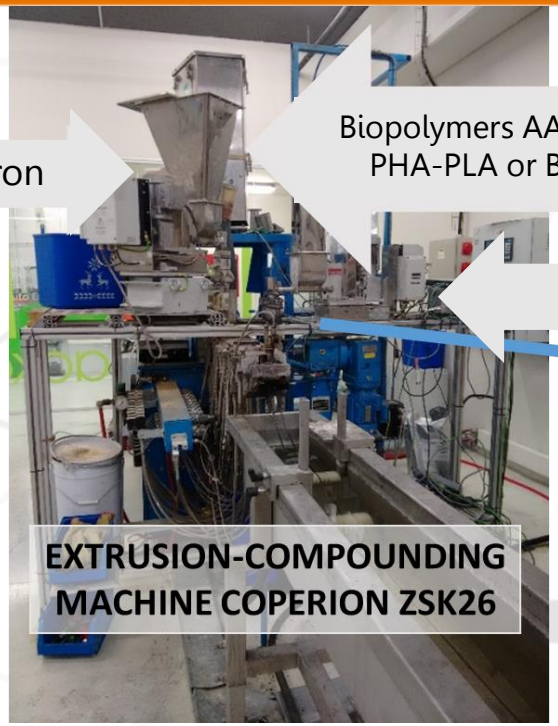
Materials & Methods: Production of bioplastics

Zn/Mn complex or Boron

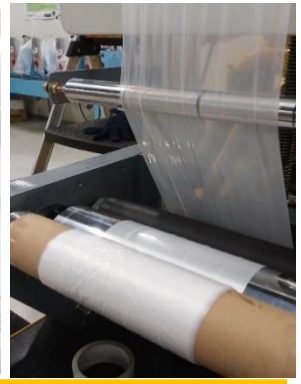


Biopolymers AAPE, Biopolymers PHA-PLA or Biopolymer PBS

Additives

Moretto X DRY
AIR T Minidryers

Film blowing unit LABTECH LF 400

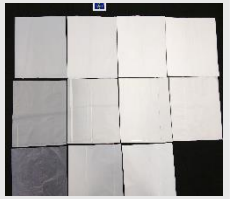


Mulching

Film for fruit bags

Semi-industrial facilities

Control samples:
Conventional LDPE mulching (Comercial Arnedo, Spain)
Conventional waxed paper bags (Cooperative Calanda DO).

Samples			Additives
MULCHING 	2016	M11	A%-B%
		M21	
		M31	
	2017	M12	A%-B%
		M42	
FRUIT BAGS 	2016	B11	A%-B%
		B21	
		B31	
	2017	B12	A%-B%
		B42	

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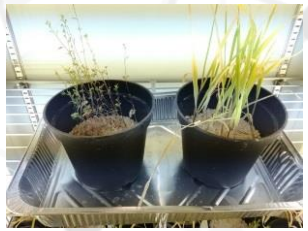
Materials & Methods: Bioplastics validation

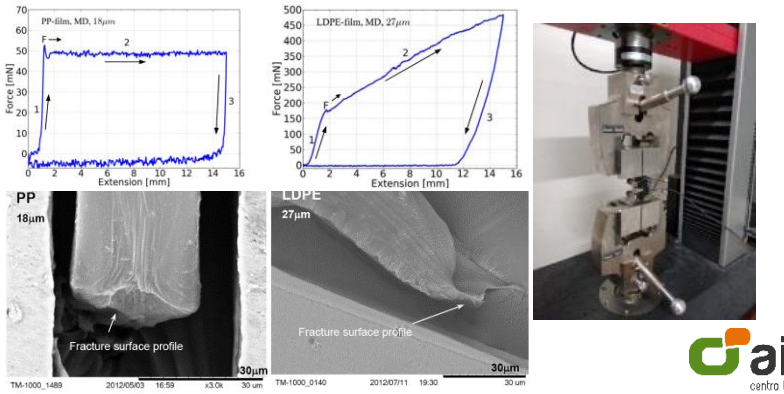


Heavy Metals concentration	**> Limits (EN 13432) = Not accepted**
Volatile solids concentration	**< 50% = Not accepted**
Biodegradation test on soil (ASTM D5988)	**< 90% within 2 years**
Final compost/ SOIL QUALITY	**Chemical-physical parameters and heavy metal NOT comply with National or European limits for Regulation on fertilizers**
Eco toxicological test on final composted residues	**< 90% compared with blank sample**

Not accepted

Laboratory plastics validation

BIOPLASTICS CHARACTERIZATION	Method
Tensile Properties of Thin Plastic Sheeting	ASTM D 882 – 12
Elasticity	ISO 604
Biodegradation test	ASTM D 5988-12
Plastics – Methods of exposure to laboratory light sources	EN:ISO 4892-3
Heavy metals concentration of the biofilms	EPA 3052 1996 EPA 6010C 2007
"OK Biodegradable Soil"	EN13432:2000



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Materials & Methods: Vegetables and fruit samples

Area Mid-Ebro Valley (Zaragoza, Spain):
Year 2016: 0,2 Ha Year 2017: 0,5 Ha

Tomato *Solanum lycopersicum "Manitu"*

- Planting dates:
  - 24/May/2016
  - 02/June/2017
- Collection dates:
  - 25/August/2016
  - 31/August/2017

Area Ebro Valley (Calanda, Spain):
1 ha, 5×4 m

Peach *Prunus persica "58GC"*

- Bagging dates (middle of season):
  - 14/July/2016
  - 17/July/2017
- Collection dates:
  - 13/September/2016
  - 06/September/2017

Materials & Methods: Soil collection and analysis

- Samples were collected randomly in each repetition of each block of plastics. Each sample was composed of 8 sub-samples taken throughout the entire line.
- Soil electrical conductivity, pH, total carbon, total N and total macro- and micronutrient was determined.
- Soil samples, only for mulching, were collected from the upper layer (20 cm).






Incorporation plastics (Y1): 28/03/17

2 months before first soil sampling

At the beginning (Y2): 24/05/2017

At the end (Y2): 03/10/2017

Incorporation plastics into the soil: 07/11/17

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Materials & Methods: Quality parameters

150 fruits per experimental unit were analysed

- CIELab colour space with the aid of a spectrophotometer (Konica Minolta mod. CMS 700; Tokyo, Japan).

- Firmness was measured with non-destructive Acoustic Firmness Sensor (AWETA; Netherlands) for peaches and Durofel (Agrosta; Forges Les Eaux, France) for tomatoes.

- Destructive Magness-Taylor using a digital penetrometer (Agrosta) with a tip diameter of 8 mm for peaches and of 4 mm for tomatoes.

- Soluble solid content (SSC) as Brix degrees was determined by crushing the flesh and transferring the intact juice of the 10 samples to a digital refractometer (Atago mod. PR-101; Tokyo, Japan).

- Titratable acidity (TA) by an automatic titrator (Mettler Toledo mod. G20 Compact Titrator; New York, NY, USA).

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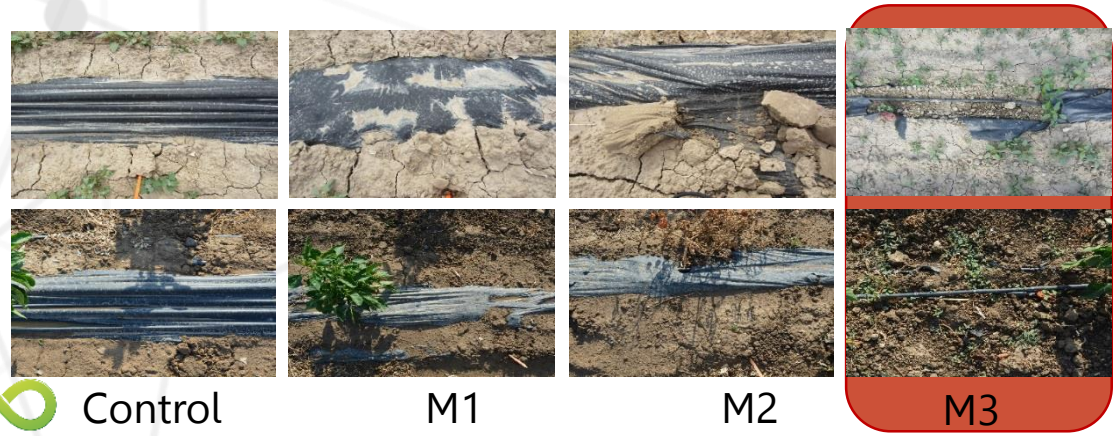
Results and Discussion

- Additives in general decrease modulus of **elasticity**.
- Moreover, oligo elements made samples bear **lower tensile stress** (σ).
- Samples **M1** were much more **resistant** to fracture (ε=552-615%) than the others, while **M31** was more **difficult to process** and manipulate.
- **Sample M12** showed the **best mechanical properties** of all samples and similar values to the conventional plastics.



Mechanical properties of **mulching** plastic films [mean (sd)]

Year	BATCH		Thickness (μm)	E (Mpa)	σ (Mpa)	ε (%)
	Material	Zn/Mn Level				
2016	M11	M11A	20 (0)	183 (69)	24.3 (2)	552 (194)
		M11B	38 (4.1)	55 (10)	8.3 (2)	615 (117)
	M21	M21A	20 (0)	166 (35)	6 (3)	235 (118)
		M21B	30 (0)	108 (29)	5.4 (1)	214 (73)
	M31	M31A	30 (0)	245 (35)	17.3 (3)	154 (10)
		M31B	30 (0)	127 (25)	12 (4)	62 (54)
	Control (LDPE)	-	42 (8)	300 (14)	4.5 (1)	600 (20)
2017	M12	M12A	31 (1.5)	190 (55)	25.5 (1.8)	430 (90)
		M12B	33 (1.2)	160 (63)	22.1 (2.2)	583 (129)
	M42	M42A	51 (4.9)	137 (60)	6.4 (2.9)	247 (88)
		M42B	40 (3.3)	122 (55)	4.9 (3.3)	226 (61)
	Control (LDPE)	-	12 (2.6)	187 (20)	26 (3.8)	280 (39)

Results and Discussion

Standard EN 13432 for compostable packaging

- The amount of oligoelements added to the mulching was calculated **for fertilization**.
- The process was **efficient preserving** the amounts of oligoelements in final plastics.
- For label "OK biodegradable SOIL" the percentage of Zn has **to be lower** than the regulation limit of 150 mg kg^{-1}.
- For fruit **protection bags**, all samples are **below the allowed limit** (data not showed).

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

Plastic Legislation

Fertilizer value

Heavy metals (mg kg^{-1} dm) in **mulching** samples (2016)									
Metal	Control	M11A	M11B	M21 A	M21B	M31A	M31B	DL (mg kg^{-1} dm)	EN 13432 (mg kg^{-1} dm)
Arsenic	<DL	<DL	<DL	<DL	<DL	<DL	<DL	2.5	5
Cadmium	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.19	0.5
Chromium	<DL	<DL	0.70	1.33	1.5	<DL	0.77	0.5	50
Mercury	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.3	0.5
Molybdenum	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.5	1
Nickel	1.15	<DL	<DL	<DL	<DL	<DL	<DL	1	25
Lead	<DL	<DL	<DL	<DL	<DL	<DL	<DL	2	50
Copper	6.63	<DL	1.61	<DL	1.70	<DL	2.39	1	50
Selenium	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.5	0.75
Zinc	<DL	5.88	1360	7.18	1700	10.5	2010	5	150

Results and Discussion

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

Volatile solids concentration → < 50% = Not accepted

Biodegradation test on soil (ASTM D5988) → **< 90% within 2 years**

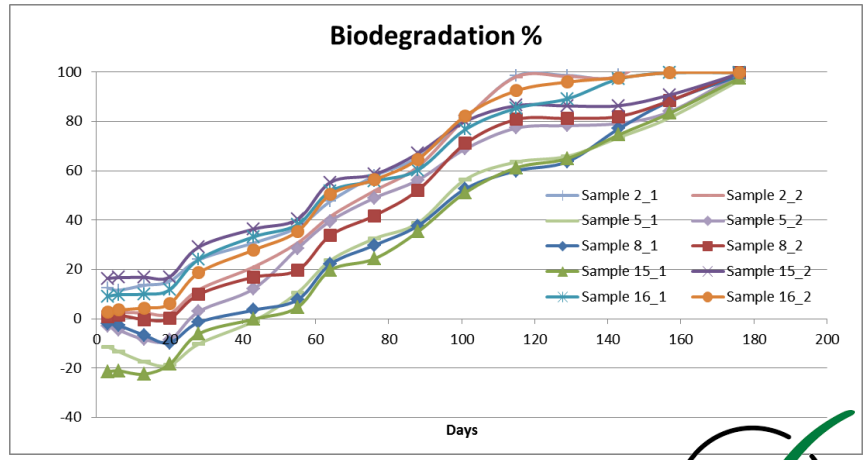
Final compost/ SOIL QUALITY → **Chemical-physical parameters and heavy metal NOT comply with National or European limits for Regulation on fertilizers**

Eco toxicological test on final composted residues → **< 90% compared with blank sample**

Not accepted

Biodegradation on soil - ASTM D5988-03

	Biodegradation (mean & sd)			
	After 143 days		After 176 days	
M11A	98,6	0,28	99,9	0,00
M21A	79,6	3,54	99,2	0,85
M31A	76,4	4,10	97,9	1,84
B31B	80,55	8,27	98,5	1,27



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SOIL OK bio-degradable VINÇOTTE

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Results and Discussion

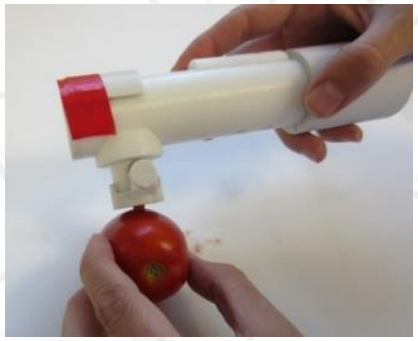
- An increase in the concentration of Mn and Zn was observed using the bioplastics (2016 results). This result shows that the **oligolements are released into the soil** after plastic degradation.
- For the macronutrients, **N was not affected**, meanwhile the concentration of **P and K was higher** using our bioplastics than control one.

Concentrations of nutrients and oligo elements in the soil[1]								
Time	BATCH		N (g 100g^{-1})	P (g 100g^{-1})	K (g 100g^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	C/N
	Material	Oligoelement Level						
Beginning of 2016 season	-	-	0.15	0.10 a	1.18 a	369.4 bc	71.2 b	34.68 a
Beginning of 2017 season and after 4 months of incorporation of the bioplastics into the soil	M11	M11A	0.16	0,10 a	1,33 bc	345,66 a	68,73 a	28,25 bc
		M11B	0.17	0,15 b	1,31 bc	363,96 b	72,16 bc	23,01 c
	M21	M21A	0.16	0,09 a	1,21 b	347,83 a	67,24 a	32,44 ab
		M21B	0.16	0,11 ab	1,32 bc	378,14 bc	73,24 bc	28,16 bc
	M31	M31A	0.17	0,10 a	1,28 bc	354,12ba	71,92 ab	25,98 c
		M31B	0.15	0,11 ab	1,47 c	383,94 c	75,49 c	30,96 b
	Control	-	0.16	0,09 a	1,23 b	342,34 a	67,03 a	31,11 b

[1]different letters in the same column indicate significant differences ($p \leq 0.05$) between treatments

Results and Discussion

- Quality tests carried out on tomatoes have also shown that fruit growth and quality, especially concerning total dry weight, soluble solids, colour and shape gave very **similar results** between using **biodegradable** plastic and **control** mulch.



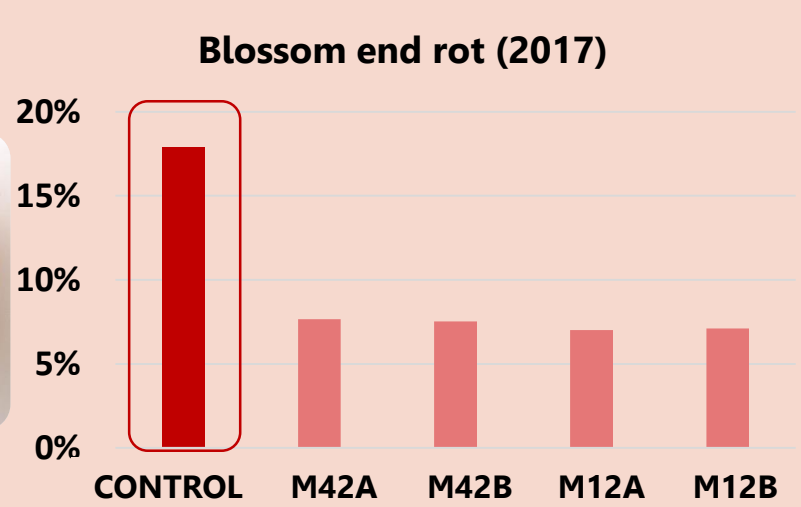
Quality parameters in 'Manitu' tomato at harvest[1]

Year	BATCH		Firmness (kg)	Durofel	Weight (g)	SSC (ºBrix)	a* (D65)	Blossom end rot (%)
	Material	Oligoelement Level						
2016	M11	M11A	0.32 a	65.04 a	102.11ab	6.73 c	32.76 ab	<1
		M11B	0.39 d	68.18 b	107.84abc	6.27 ab	34.17 c	<1
	M21	M21A	0.38 cd	70.26 b	97.97a	6.60 bc	31.69 a	<1
		M21B	0.38 bcd	68.90 b	105.5abc	6.23 ab	33.12 bc	<1
	M31	M31A	0.39 cd	63.62 a	113.42c	5.93 a	31.99 ab	<1
		M31B	0.34 abc	68.76 b	102.54ab	6.70 c	32.75 ab	<1
	Control	-	0.33 ab	69.02 b	110.42bc	6.73 c	33.22 bc	<1
2017	M12	M12A	0.44 bc	68.06	143.75	6.47	32.24	7 a
		M12B	0.48 c	70.72	140.33	6.3	32.51	7 a
	M42	M42A	0.43 bc	69.17	146.99	6.5	32.48	8 a
		M42B	0.37 a	69.21	128.58	6.53	31.23	8 a
	Control	-	0.41 ab	70.88	141.48	6.33	32.04	18 b

[1]different letters in the same column indicate significant differences ($p \leq 0.05$) between treatments for the same year.

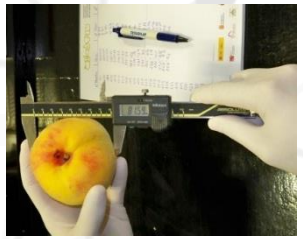
Results and Discussion

- In 2016 season, although significant differences were observed, there was **no clear pattern** in the use of different plastics for tomatoes. In 2017 season, **no differences were observed**, showing that the plastics did not have effect in these quality parameters.
- **Only remarkable** that in 2017 **the incidence of blossom end rot**, a water-soaked spot located at the blossom end of tomato fruits, was **higher in the control** (18%) **than in bioplastics** M12 (7%) and M42 (8%). This result could be related with a different temperature in the soil of each plastic, different reflected sunlight, or even the Zn/Mn concentration but it is necessary more assays to confirm this hypothesis.



Results and Discussion

- Firmness, weight, acidity and soluble solids of the peaches **were not affected** by using biobags. Differences observed may be due to intrinsic differences in crops more than effect of the bioplastics.
- A **lower red coloration** in the fruits (lower coordinate a* value) and a **more homogeneous** yellowish colour. These values were also lower than the control ones.



Quality parameters in '58GC' peach at harvest[1]

Year	BATCH		Firmness (kg)	Aweta	Weight (g)	T.A. (g.malic L^{-1})	SSC (ºBrix)	a* (D65)
	Material	WP%						
2016	B11	B11A	3.19	10.03	220.83	5.64 ab	14.03 c	14.88 bc
		B11B	3.23	9.55	235.17	5.85 b	14.58 c	14.49 ab
	B21	B21A	3.24	12.79	232.27	5.14 a	12.93 ab	15.76 bcd
		B21B	3.03	13.23	230.00	5.14 a	12.35 a	13.34 a
	B31	B31A	3.20	8.81	207.53	6.02 b	14.70 c	16.05 cd
		B31B	3.23	12.87	221.30	5.51 ab	13.08 b	13.16 a
	Control	-	3.21	15.09	233.77	5.18 a	12.78 ab	16.40 d
2017	B12	B12A	2.56 b	9.32 a	215.46	6.75 a	13.43	15.45 c
		B12B	2.21 ab	9.64 ab	221.92	6.87 a	13	14.14 b
	B42	B42A	2.06 a	11.63 abc	211.58	7.26 a	12.63	15.62 c
		B42B	3.62 c	13.9 c	233.19	7.77 a	12.6	12.39 a
	Control	-	2.11 ab	11.88 bc	217.69	9.38 b	13.13	15.37 c

[1]different letters in the same column indicate significant differences ($p \leq 0.05$) between treatments for the same year.

Results and Discussion

Control

Lower WP %

Higher WP %

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AGENDA//

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Introduction: General overview of the project

Materials and Methods

Results and Discussion

Conclusions

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Conclusions

The following conclusions can be drawn from the study:

- Additives (oligoelements and/or colourants) made more difficult plastic processing. In general, all selected bioplastics showed appropriate mechanical properties.
- Adequate biodegradation in the field and in the laboratory was observed with selected bioplastics.
- The addition of Zn is not proper to obtain the "OK biodegradable SOIL" certification, but fertilization effect was reached: higher concentration of Mn and Zn than in control samples was founded in the soil.
- Biomulching in tomatoes decreased the incidence of blossom end rot, improving the production, and not affecting to the rest of quality parameters.
- For peaches, the colour obtained with biobags was more uniform and yellowish than with conventional bags without modifying other quality parameters, improving their sell value for the producers.

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Merci pour votre attention
Thank you for your attention
Gracias por su atención

Biodegradable plastics for improving soil and fruit quality characteristics

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