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

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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](http://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

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

Agricultural film 2017
Barcelona, 26-28 September 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...
Agroplastics are needed:

- Conserve water and nutrients
- Prevent weed growth
- Permit adequate temperature in the rhizosphere
- Protection against pests and infestations
- Isolate fruit from plant protection products
- Fruit with uniform skin colour
- Conserve water and nutrients
- Prevent weed growth
- Permit adequate temperature in the rhizosphere
- Protection against pests and infestations
- Isolate fruit from plant protection products
- Fruit with uniform skin colour

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.

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.
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)

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 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 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.

- Ethanol $\rightarrow$ Ethylene
  - Polyethylene (PE)
- Lactic acid $\rightarrow$ Lactide
  - Polylactic acid
- Succinic acid, Butanediol
  - Polybutylene succinat (PBS)
- 1,3-Propanediol
  - Polytrimethylene terephthalate (PTT)
- Furandicarboxylic acid
  - Polyethylene furanoate (PEF)
- Polyhydroxyalkanoates (PHA)
- Fatty acids from plant oils
  - Dicarboxylic acids (e.g. azelaic acid)
  - Polyester (LCDA)

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

Source: European Bioplastics

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Agricultural film 2017

Barcelona, 26-28 September 2017

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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

- Moretto X DRY AIR T Minidryers

- Extrusion-compounding machine Coperion ZSK26

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

- Oligo elements
- Carbon Black
- T³ control
- Material flow control
- % components
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

<table>
<thead>
<tr>
<th>Samples (materials)</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>MULCHING 3% oligoel.</td>
<td>M1-M3</td>
</tr>
<tr>
<td></td>
<td>2 thickness</td>
</tr>
<tr>
<td>N</td>
<td>N1-N3</td>
</tr>
<tr>
<td></td>
<td>3 thickness</td>
</tr>
<tr>
<td>P</td>
<td>P1-P3</td>
</tr>
<tr>
<td></td>
<td>1 thickness</td>
</tr>
<tr>
<td>FRUIT BAGS 2% and 2 different colour</td>
<td>M4-M7</td>
</tr>
<tr>
<td></td>
<td>40 μm</td>
</tr>
<tr>
<td>N</td>
<td>N4-N6</td>
</tr>
<tr>
<td></td>
<td>35 μm</td>
</tr>
<tr>
<td>O</td>
<td>O1-O3</td>
</tr>
<tr>
<td></td>
<td>50 μm</td>
</tr>
</tbody>
</table>

Width Thickness Dispersion

Mulching Film for fruit bags
### 6. Laboratory plastics validation

<table>
<thead>
<tr>
<th>BIOPLASTICS CHARACTERIZATION</th>
<th>Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Properties</strong> of Thin Plastic Sheeting</td>
<td>ASTM D 882 – 12</td>
<td>&gt; Limits (EN 13432) = Not accepted</td>
</tr>
<tr>
<td><strong>Tear-Propagation Resistance</strong> of Plastic Film and Thin Sheeting by a Single-Tear Method</td>
<td>ASTM D 1938 –14</td>
<td>&gt; 50% = Not accepted</td>
</tr>
<tr>
<td><strong>Flexural Properties</strong> of Unreinforced and Reinforced Plastics and Electrical Insulating Materials</td>
<td>ASTM D 790 – 15</td>
<td>&lt; 90% within 2 years</td>
</tr>
<tr>
<td>Plastics – Methods of exposure to laboratory light sources</td>
<td>EN:ISO 4892-3</td>
<td>Chemical-physical parameters and heavy metal NOT comply with National or European limits for Regulation on fertilizers</td>
</tr>
<tr>
<td>Standard Test Method for Oxidative-Induction Time of Polyolefin by Differential Scanning Calorimetry</td>
<td>ASTM D3985 - 10</td>
<td>&lt; 90% compared with blank sample</td>
</tr>
<tr>
<td><strong>Water Vapor Transmission Rate</strong> Through Plastic Film and Sheeting Using a Modulated Infrared Sensor</td>
<td>ASTM F1249 - 13</td>
<td>“OK Biodegradable Soil”</td>
</tr>
</tbody>
</table>

#### “OK Biodegradable Soil”

- EN13432:2000
6. Laboratory plastics validation

**Heavy metals content in plastic samples**

- **EN 13432:2000**: Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging.


- **prEN 17033:2016** *Plastics - Biodegradable mulch films for use in agriculture and horticulture - Requirements and test methods.*

<table>
<thead>
<tr>
<th>Plastic</th>
<th>As (mg/kg dm)</th>
<th>Cd (mg/kg dm)</th>
<th>Cr (mg/kg dm)</th>
<th>Hg (mg/kg dm)</th>
<th>Mo (mg/kg dm)</th>
<th>Ni (mg/kg dm)</th>
<th>Pb (mg/kg dm)</th>
<th>Cu (mg/kg dm)</th>
<th>Se (mg/kg dm)</th>
<th>Zn (mg/kg dm)</th>
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</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>1,15</td>
<td>&lt;DL</td>
<td>6,73</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
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<tr>
<td>N2</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>0,751</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>1,24</td>
<td>&lt;DL</td>
<td>766</td>
</tr>
<tr>
<td>M1</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>1,33</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>7,18</td>
</tr>
<tr>
<td>M7</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>1,81</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>&lt;DL</td>
<td>581</td>
<td>&lt;DL</td>
</tr>
<tr>
<td>DL</td>
<td>2,5</td>
<td>0,19</td>
<td>0,5</td>
<td>0,3</td>
<td>0,5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0,5</td>
<td>5</td>
</tr>
<tr>
<td>EN 13432</td>
<td>5</td>
<td>0,5</td>
<td>50</td>
<td>0,5</td>
<td>1</td>
<td>25</td>
<td>50</td>
<td>50</td>
<td>0,75</td>
<td>150</td>
</tr>
</tbody>
</table>

> Limits (EN 13432) = Not accepted

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**Plastic Legislation**

**Fertilizers values**
6. Laboratory plastics validation

**Heavy metals content in plastic samples**


COM(2016) 157

- 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)

SOIL

H₂O

CH₄

CO₂

Visual assessment

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

<table>
<thead>
<tr>
<th>Biodegradation (mean and standard deviation)</th>
<th>After 143 days</th>
<th>After 176 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>98,6</td>
<td>0,28</td>
</tr>
<tr>
<td>M1</td>
<td>79,6</td>
<td>3,54</td>
</tr>
<tr>
<td>P1</td>
<td>76,4</td>
<td>4,10</td>
</tr>
<tr>
<td>O2</td>
<td>80,55</td>
<td>8,27</td>
</tr>
<tr>
<td>O3</td>
<td>97,55</td>
<td>0,35</td>
</tr>
</tbody>
</table>

1. Heavy Metals
2. Biodegradation: Plastic in soil samples (ASTM D5988)
6. Laboratory plastics validation

MULCHING

FRUIT BAGS
7. Validation of products in field

**MULCHING**

<table>
<thead>
<tr>
<th>Product</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomulching</td>
<td>648 m²</td>
<td>2,664 m²</td>
<td>2,016 m²</td>
</tr>
<tr>
<td>Biobags</td>
<td>900</td>
<td>3,700</td>
<td>2,800</td>
</tr>
<tr>
<td>Bioclips</td>
<td>900</td>
<td>3,700</td>
<td>2,800</td>
</tr>
</tbody>
</table>

- 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)
Years 2017 and 2018: 0,5 Ha (Spain)
Proof concept Belgium and France

**Products:**
- **Tomato 'Manitu'**
- **Red Pepper 'Morrón'**
- **Cucumber 'Uranus'**

**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 (%)

**Control**

- M3
- M2
- M1
- N3
- N2
- N1
- P3
- P2
- P1
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 (%)

<table>
<thead>
<tr>
<th>Product</th>
<th>Phase1</th>
<th>Phase2</th>
<th>Phase3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomulching</td>
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<td>2,800</td>
</tr>
<tr>
<td>Bioclips</td>
<td>900</td>
<td>3,700</td>
<td>2,800</td>
</tr>
</tbody>
</table>

- Peach field
  - 1 ha
  - 5×4 m
  - Drip irrigation

- Apple field
  - 1 ha
  - 5×4 m
  - Drip irrigation

- September Peach
- Fuji Apple

- Two months of bagging
- Biobags are easy to put at the tree
8. Preharvest quality measurements

Chlorophyll per leaf area unit
Must be 40 units

Chlorophyll fluorescence
Must be Fv/Fm = 0.7

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

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>NUTRITIONAL compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lycopene</td>
</tr>
<tr>
<td></td>
<td>Vitamin C</td>
</tr>
<tr>
<td></td>
<td>Polyphenols</td>
</tr>
<tr>
<td></td>
<td>Vitamin C</td>
</tr>
<tr>
<td></td>
<td>Polyphenols</td>
</tr>
<tr>
<td></td>
<td>Chlorophyll</td>
</tr>
<tr>
<td></td>
<td>Polyphenols</td>
</tr>
</tbody>
</table>

## Nutritional compounds

<table>
<thead>
<tr>
<th></th>
<th>PHENOLS (mg/100g)</th>
<th>Chla (µg/g)</th>
<th>Chlb (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>s.d.</td>
<td>mean</td>
</tr>
<tr>
<td>material</td>
<td>additive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13,24</td>
<td>1,77</td>
<td>2,93</td>
</tr>
<tr>
<td>2</td>
<td>12,11</td>
<td>1,69</td>
<td>3,04</td>
</tr>
<tr>
<td>3</td>
<td>11,42</td>
<td>0,57</td>
<td>2,45</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13,76</td>
<td>1,52</td>
<td>2,56</td>
</tr>
<tr>
<td>2</td>
<td>12,76</td>
<td>0,28</td>
<td>2,98</td>
</tr>
<tr>
<td>3</td>
<td>11,36</td>
<td>0,76</td>
<td>2,46</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>11,24</td>
<td>0,76</td>
<td>3,17</td>
</tr>
<tr>
<td>2</td>
<td>10,79</td>
<td>2,20</td>
<td>4,30</td>
</tr>
<tr>
<td>3</td>
<td>13,89</td>
<td>2,04</td>
<td>3,56</td>
</tr>
<tr>
<td>control</td>
<td>-</td>
<td>1,07</td>
<td>4,25</td>
</tr>
<tr>
<td>sign.</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

No significate differences were founded.
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.

### PEACH BAGS EFFECTS

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>oBrix</th>
<th>a*</th>
</tr>
</thead>
<tbody>
<tr>
<td>nº</td>
<td>material</td>
<td>external</td>
</tr>
<tr>
<td>1</td>
<td>N opaque</td>
<td>14.58 c</td>
</tr>
<tr>
<td>2</td>
<td>N translucent</td>
<td>14.03 c</td>
</tr>
<tr>
<td>3</td>
<td>O opaque</td>
<td>13.08 b</td>
</tr>
<tr>
<td>4</td>
<td>O translucent</td>
<td>14.70 c</td>
</tr>
<tr>
<td>5</td>
<td>M opaque</td>
<td>12.35 a</td>
</tr>
<tr>
<td>6</td>
<td>M translucent</td>
<td>12.93 ab</td>
</tr>
<tr>
<td>c CONTROL WP</td>
<td>12.78 ab</td>
<td>0.29</td>
</tr>
</tbody>
</table>

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

### SAMPLE

<table>
<thead>
<tr>
<th>Nº</th>
<th>Material</th>
<th>External</th>
<th>Mean (mg/100g)</th>
<th>d.s.</th>
<th>Mean (µg/g) Xanthophyll + Carotenoids</th>
<th>d.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N</td>
<td>opaque</td>
<td>46.62 ab</td>
<td>6.21</td>
<td>12.94 a</td>
<td>4.58</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
<td>translucent</td>
<td>53.63 b</td>
<td>13.34</td>
<td>19.87 ab</td>
<td>4.55</td>
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<tr>
<td>3</td>
<td>O</td>
<td>opaque</td>
<td>31.36 a</td>
<td>11.52</td>
<td>16.51 ab</td>
<td>4.24</td>
</tr>
<tr>
<td>4</td>
<td>O</td>
<td>translucent</td>
<td>58.43 b</td>
<td>4.79</td>
<td>22.41 b</td>
<td>2.09</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>opaque</td>
<td>29.38 ab</td>
<td>6.83</td>
<td>13.52 a</td>
<td>0.14</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>translucent</td>
<td>39.14 a</td>
<td>11.95</td>
<td>14.45 a</td>
<td>2.79</td>
</tr>
<tr>
<td>c</td>
<td>CONTROL</td>
<td>WP</td>
<td>49.78 ab</td>
<td>14.53</td>
<td>14.30 a</td>
<td>4.56</td>
</tr>
</tbody>
</table>

**Significant difference**: 0.029 0.048
9. Post-harvest quality measurements

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

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>°Brix</th>
<th>Coordinate a*</th>
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<tbody>
<tr>
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<tr>
<td>nº</td>
<td>color</td>
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</tr>
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<td>White</td>
<td>16,23abc</td>
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<tr>
<td>2</td>
<td>Red</td>
<td>16,83bc</td>
</tr>
<tr>
<td>3</td>
<td>White</td>
<td>16,13abc</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>17,37c</td>
</tr>
<tr>
<td>5</td>
<td>White</td>
<td>16,47abc</td>
</tr>
<tr>
<td>6</td>
<td>Red</td>
<td>15,77abc</td>
</tr>
<tr>
<td>7</td>
<td>Blue</td>
<td>14,70a</td>
</tr>
<tr>
<td>P</td>
<td>WP</td>
<td>15,33ab</td>
</tr>
<tr>
<td>C</td>
<td>CONTROL no bag</td>
<td>14,83a</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>ANTOCIANS (mg eq C3Glucosido/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>nº</td>
<td>material</td>
</tr>
<tr>
<td>1</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>O</td>
</tr>
<tr>
<td>4</td>
<td>O</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
</tr>
<tr>
<td>P</td>
<td>WP</td>
</tr>
<tr>
<td>C</td>
<td>CONTROL</td>
</tr>
</tbody>
</table>

sign. 0,025
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.

<table>
<thead>
<tr>
<th>PLAGUE/Nº TREATMENTS</th>
<th>BAG LESS</th>
<th>BAGGED</th>
</tr>
</thead>
<tbody>
<tr>
<td>G. MOLESTA Y A. LINEATA</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>C. CAPITATA</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>14 (12)</td>
<td>6</td>
</tr>
</tbody>
</table>

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
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.

*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)

*** $\rho$ (PE) = 0,9 g/cm$^3$ & $\rho$ (bio) = 1,26 g/cm$^3$
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...

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 → Biodegradable 0,0003 €/bag

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

RD 533/2017, of May 26, which regulates the funds and operational programs of organizations of producers of fruit and vegetables.
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.
  - Macroporeformations 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).
Thank you for your attention

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carolina.penalva@aitiip.com