The new European Standard BS EN 17033 for biodegradable mulch films

Scientific findings on full biodegradability in soil

London, 21/11/18
Use of mulch films in agriculture and horticulture: – Functions and benefits:

Soil mulching enhances growing conditions and contributes to increased yields and improved crop quality by:

- Earlier planting dates
- Earlier harvesting dates
- Inhibiting the development of weeds
- Soil moisture retention
- Reduction in leaching of mineral elements and other fertilizer
- Protecting leaves and fruits against soil-borne diseases
- Protecting the crops from soil
- Reduction in soil compaction

► The improvement growing conditions are the same for biodegradable mulch films as those for conventional mulch films
Disposal of mulch films at the end of the intended service life:
– Material recycling or biodegradation?

- Thin films with high soil „attachment rate“ hinder used film collection
- Recommended thickness to enable conventional mulch film collection and recycling is ≥25 µm
- Reduction of operational costs by using biodegradable mulch films

<table>
<thead>
<tr>
<th>Application type</th>
<th>Soil “attachment” rate</th>
<th>Thickness</th>
<th>Trucks of virgin film</th>
<th>Trucks to send back used mulch film</th>
<th>Tonnage of “attachment” to carry and eliminate per truck of 25t virgin film</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse</td>
<td>20%</td>
<td>200µ</td>
<td>1</td>
<td>1.2</td>
<td>5 t</td>
</tr>
<tr>
<td>Mulch</td>
<td>70%</td>
<td>25µ</td>
<td>1</td>
<td>3</td>
<td>58 t</td>
</tr>
<tr>
<td>Thin mulch</td>
<td>80%</td>
<td>15µ</td>
<td>1</td>
<td>5</td>
<td>100 t</td>
</tr>
</tbody>
</table>

“attachment”: crop residues, weeds, clay, sand, water…

References:
- prEN 13655:2016 – Plastics – Thermoplastic mulch films recoverable after use, for use in agriculture and horticulture (2016-09)
Disposal of mulch films at the end of the intended service life:
– Material recycling or biodegradation?

► Disposal of used agricultural plastic in the EU:

► Most agricultural films are not regularly collected and recovered due to the high „attachment rate“ of up to 80%

Source: EPRO
ecovio® M2351 mulch –
Biodegradation in soil according to ISO 17556

At 181 days an absolute biodegradation of 94.4% (±1.7%) was measured = 89.1% relative to cellulose
BS EN 17033:2018 “Biodegradable mulch films for use in agriculture and horticulture – requirements and test methods”

Control of constituents

Biodegradability

EN 17033

Dimensional, mechanical and optical properties

Ecotoxicity

Transfer into certification schemes

New working item proposal to ISO
ecovio® is a compound consisting of:

- Biodegradable and (partly bio based) BASF-Polyester ecoflex®
- Bio based polylactic acid (PLA)
- [Mineral fillers ]
Let’s talk about end of life Basics and Standards

- Mineralization by natural organisms to CO$_2$ and microbial biomass
- CO$_2$ is indicator for biodegradability measurement
- 10% of carbon is estimated to go into biomass, 90% of carbon goes in CO$_2$\(^1\)

Basic understanding and field evaluation are both needed to understand biodegradability

**Fundamental understanding**
- Elucidating structure-biodegradability relationship
- Polymer characteristics
  - Microorganisms and enzymes
  - Abiotic factors
- Microbial profiling
cultivation
enzyme characterization

**Field evaluation**
- Assessing product performance in field trials
What is ecoflex®?

3 Monomers together build a long chain polymer

Terephthalic acid  Butanediol  Adipic acid

ester bond
Process of biodegradation of PBAT

1. Microbial colonization of the surface and excretion of enzymes (e.g. cutinases)

2. Enzymatic hydrolysis of ester bonds

3. Release of water soluble fragments

4. Uptake and metabolism by microbes

Extracellular enzymes

Microbes

Biodegradable polymer (e.g. ecoflex®)

Ester bond

CO₂

H₂O

Watersoluble fragments
1. Microbial colonization
Polyester (PBAT) in agricultural soil

Laboratory experiments
Incubations in agricultural soil → 6 weeks @ 25°C

Scanning electron microscopy images
Process of biodegradation of PBAT

1. Microbial colonization of the surface and excretion of enzymes (e.g. cutinases)
2. Enzymatic hydrolysis of ester bonds
3. Release of water soluble fragments
4. Uptake and metabolism by microbes

Where does the carbon end up? Does ecovio® M fully biodegrade?
4. Microbial metabolism
How to show the biomass formation?

By tracing marked carbon in the polymer!

https://youtu.be/ii1uvRHXOE

[Diagram of molecular structures with Adipic acid, Butanediol, and Terephthalic acid, indicating the presence of $^{13}$C labeled atoms in PB*AT, P*BAT, and PBA*T molecules.]
4. Microbial metabolism
How to show the biomass formation?

1. Microbial colonization of the surface and excretion of enzymes (e.g. cutinases)

2. + 3 Enzymatic hydrolysis of ester bonds and release of watersoluble fragments

4. Uptake and metabolization by microbes ➔ Formation of biomass from labelled carbon

- Labelled carbon
- Polymer with labelled carbon
- Fungal hypha and bacteria
- Water soluble fragment with labelled carbon
- Enzyme
- Fungal hypha and bacteria with labelled biomass
4. Microbial metabolism
Conversion into microbial biomass

Nanoscale secondary ion mass spectrometry (NanoSIMS)

poly(butylene adipate-co-terephthalate)
PBAT: labeled in adipate

$^{13}$C atom percent

$^{13}$C / ($^{12}$C + $^{13}$C) (%)

Zumstein et al., Science Advances, Biodegradation of synthetic polymers in soils: Tracking carbon into CO$_2$ and microbial biomass, 2018
4. Microbial characterization

Microflora is a dominating factor

➡️ Who is eating our product?

1. DNA isolation & community analysis
2. isolation from soil → cultivation → characterization
3. direct isolation from partially degraded polymer

Exemplary soil organisms (not necessarily ecovio degraders)
4. Microbial characterization
Tracing the label in DNA

DNA - Stable Isotope Probing ($^{13}$C DNA-SIP)

- Incubation, extraction of total DNA ($^{12}$C & $^{13}$C strands)
- Separation via ultracentrifugation
- Fractionation
- Labeled metagenome

Incubation time [d]

Biodegradation [%]

0% 20% 40% 60% 80% 100%

0 50 100 150

unlabeled control $^{13}$C-labeled polymer fully labeled control

$^{12}$C DNA $^{13}$C DNA

$^{12}$C-DNA $^{13}$C-DNA
Cooperation ETH Zürich and BASF on biodegradation in soil

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→ Landmarking cooperation for sustainable chemistry
Recommendation for Policy Makers

→ All agricultural films marketed as “degradable” or “biodegradable” to meet British standard BS EN 17033:2018
4. Microbial characterization
Tracing the label in DNA

Bacteria

Fungi
(ITS region)

PBS = poly(butylene succinate)
Process of biodegradation of PBAT

1. Microbial colonization of the surface and excretion of enzymes (e.g. cutinases)
2. Enzymatic hydrolysis of ester bonds
3. Release of water soluble fragments
4. Uptake and metabolization by microbes

CO₂ → H₂O → extracellular enzymes → microbes → biodegradable polymer (e.g. ecoflex®) → ester bond → watersoluble fragments
2. Enzymatic hydrolysis
Polyester (PBAT) hydrolysis

4. Microbial characterization

Phylogeny of primary disintegrating microbes

- Isolation of microorganisms directly from partial degraded polymer films (→ more than 400 isolates, esp. fungi)

- Fungi have been identified to be the most potent but not exclusively degrading microorganisms in soil
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