Biodegradable Plastic Mulch

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www.biodegradablemulch.org


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Overall Research Project

- Sociology
- Economics
- Material Science
- Horticulture
- Plant Pathology
- Soil Ecology
- Sociology
- Economics
Overall Research Project

- Soil Ecology
- Horticulture
- Plant Pathology
- Material Science
- Sociology
- Economics
Field Experiment

Mount Vernon, Washington

Knoxville, Tennessee
Field Experiment
Field Experiment
Field Experiment
Biodegradable Plastic

Questions:

1. Does biodegradable plastic affect soil health?

2. Does biodegradable plastic degrade completely in soil?

3. Are residues released during degradation?
Soil Health Assessment

![Graph showing change in aggregate stability (%).](image)

- **Knoxville, TN**
- **Mount Vernon, WA**

Legend:
- No-mulch
- Naturecycle
- Polyethylene
- Paper
- Organix
- BioAgri
- PLA/PHA

*2015-2017*
Soil Health Assessment

2015-2017

Tennessee

Washington

Microbial Communities
Biodegradable Plastic Mulches

1. Similar agronomic benefits
2. No short-term effects of mulches on soil health
3. Seasonal changes more pronounced than mulch effects
4. Soil health is a slow changing process

=> long-term study needed
Biodegradable Mulch Film Basics

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QUESTIONS

1. What is the effect on overall soil health, including soil biology, when this material biodegrades?

2. What is the cumulative effect of the continued use of this biodegradable biobased mulch film, on soil nutrient balance, soil biological life, and soil tilth, when used in the same area of the field for 3-5-10 years?

3. What effect does the breakdown of these polymers have on soil and plant life as well as livestock that would graze either crop residues or forages grown the subsequent year after this mulch film was used?

4. Are there different cropping systems, climate, soil types or other factors that affect the decomposition rate (Examples would be long cold winters, or exceptionally dry conditions, such as found in a desert)?

5. Are there metabolites of these mulches that do not fully decompose, and if so, is there an effect upon soil health or biological life?

6. Can you provide information on the existence or development of biobased biodegradable mulch films that would meet the requirements of NOP policy memorandum 15-1?
What does “Biodegradable” Mean?

Can the microorganisms in the target disposal system (composting, soil, anaerobic digestor) assimilate/utilize the carbon substrate as food source completely and in a short defined time period?

**STEP 1**

Environment – soil, compost, waste water plant, marine

Hydrolytic Oxidative Enzymatic

Polymer chains with susceptible linkages

**Oligomers & polymer fragments**

**STEP 2**

Complete microbial assimilation

defined time frame, no residues

**CO₂ + H₂O + Cell biomass**

**Biodegradation (Step 2):** Only if all fragmented residues consumed by microorganisms as a food & energy source as measured by evolved CO₂ in defined time and disposal environment
Basics of microbial utilization -- biodegradability

- Microorganisms utilize carbon substrates as “food” to extract chemical energy for their life processes.

- They do so by transporting the C-substrate inside their cells and:

- Under aerobic conditions, the carbon is biologically oxidized to CO$_2$ releasing energy that is harnessed by the microorganisms for its life processes. Under anaerobic conditions, CO$_2$+CH$_4$ are produced.

- Thus, a measure of the rate and amount of CO$_2$ or CO$_2$+CH$_4$ evolved as a function of total carbon input to the process is a direct measure of the amount of carbon substrate being utilized by the microorganism (percent biodegradation)

\[
\text{Glucose/C-bioplastic} + 6\text{ O}_2 \rightarrow 6\text{ CO}_2 \uparrow + 6\text{ H}_2\text{O}; \quad \Delta G^0 = -686 \text{ kcal/mol}
\]

\[
\text{Glucose/C-bioplastic} \rightarrow 2\text{ lactate}; \quad \Delta G^0 = -47 \text{ kcal/mol}
\]

\[
\text{CO}_2 + \text{CH}_4 \uparrow
\]
The level of biodegradation needed to claim safe and efficacious removal of the plastic carbon from the environmental compartment.

**biodegradation phase**

**lag phase**

**plateau phase**

ASTM D5988; ISO 17556 -- Soil biodegradability test method
EN 17033 – soil biodegradability specifications for biodegradable mulch film
CAUTION!!!

Unqualified use of the term “biodegradable” is wrong, misleading, and deceptive. It violates the law in the State of California and U.S. Federal Trade Commission (FTC) green guides & in Australia too

- Need to define disposal environment, time/rate and extent of biodegradation – qualified biodegradability claim
  - Soil biodegradability (mulch films & ag products)
  - Compostable plastics -- enabler for food and organic waste diversion from landfills to composting

- Need complete microbial assimilation and removal from the environmental compartment in a short time period otherwise may have environmental and health consequences
  - Degradable, partial biodegradable not acceptable – serious health and environmental consequences

- Phil. Trans. Royal. Soc. (Biology) July 27, 2009; 364
Misleading (Green Washing) Claims -- Additive Technology

• “Plastic products with our additives at 1% levels will fully biodegrade in 9 months to 5 years wherever they are disposed like composting, or landfills under both aerobic and anaerobic conditions”

The 50% Bio-Batch film did not degrade as completely or as quickly as the cellulose. At the end of the test, 19% of the film had degraded.

The results of the aerobic degradation tests indicate that, in time, plastics produced using Bio-Batch pellets will biodegrade in aerobic conditions.

DATA DOES NOT SUPPORT THE CONCLUSIONS!
MISUSE OF BIODEGRADABILITY CLAIMS

  - A hypothesis was developed, and successfully tested, to greatly increase the rates of biodegradation of polyolefins, by anchoring minute quantities of glucose, sucrose or lactose, onto functionalized polystyrene (polystyrene-co-maleic anhydride copolymer) and measuring their rates of biodegradation, which were found to be significantly improved.

PRESS

- Sugar turns plastics biodegradable. Bacteria make a meal of sweetened polythene and polystyrene.

weight loss of only 2-12%,

Only sugar is being assimilated, PE chain intact – Is this a genuine example of biodegradable plastic?
Aliphatic-aromatic copolyester

C-14 label on aromatic carbon – the most recalcitrant component

Terephthalic acid  \( \text{Diol} \)  Aliphatic diacid

Copolyester

\[ T_m \sim 110 - 125 \, ^\circ\text{C} \]

Completely Biodegradable (microbial assimilation) under composting conditions

BASF
KingFa
Showa
Mitsubishi
Novamont
Biodegradability/Composting Data
Profile of BioPlast Film T-101

Aliphatic-aromatic copolyester

Carbon Balance

Using ASTM D6340 and Carbon\textsuperscript{14} techniques, very accurate collection of data and a carbon balance are possible for BioPlast Film T-101. Standard respirometer methods may incorporate >20\% "priming" error.

Aromatic ring carbons, the most recalcitrant component is assimilated by the compost microorganisms as seen by evolution of the C-14 carbon dioxide
“Carbon from each monomer unit of PBAT was used by soil microorganisms, including filamentous fungi, to gain energy and to form biomass”

Biomass refers to cellular biomass – PBAT carbons incorporated into lipid molecules

Biobased plastics/products refers to the “beginning of life”

- Origins of the carbon in the polymer
- Plant-biomass feedstock (biobased) vs petro-fossil feedstock
WHY BIOBASED??

What are the benefits of replacing petro/fossil carbon with biocarbon?

- Reduced carbon footprint
- Food security and creating value for rural agrarian economy
- Create “wealth” in rural agriculture through value-added industrial products

CAUTION:
Need to still address the issue of end-of-life mechanical, chemical, biological/organic recycling
Understanding “BIOBASED & BIODEGRADABILITY” at Molecular level

Biobased plastics are NOT necessarily biodegradable/compostable

Biodegradable-Compostable Plastics are NOT necessarily Biobased
Thank You