

Understanding ASTM Standards and Biodegradability of Plastics

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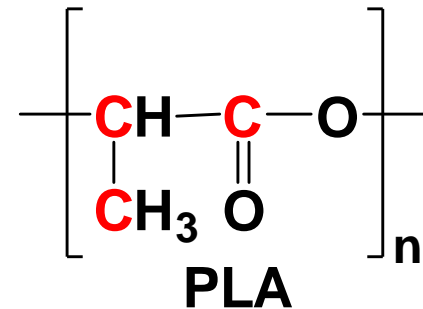
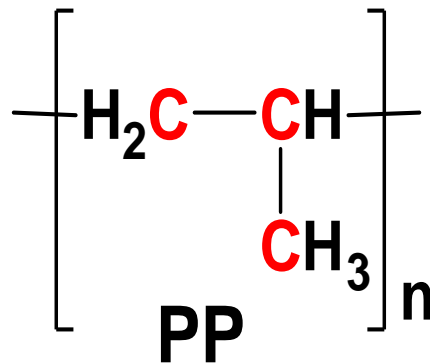
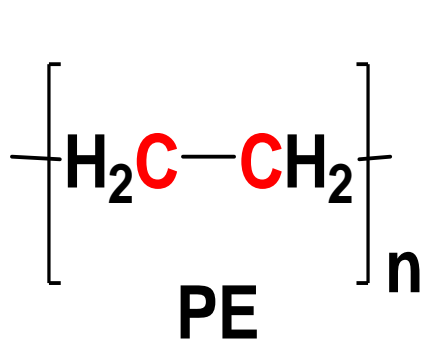
UNDERSTANDING TERMINOLOGY

BIOBASED; BIODEGRADABLE, COMPOSTABLE PLASTICS

- **Biobased** or **biomass** or **renewable/renewably** sourced plastic mean the same and can be used interchangeably but they are **not necessarily** biodegradable - compostable
 - Beginning of life – replacement of petro carbon with bio-renewable carbon and offers the value proposition of a reduced carbon footprint, and energy security
- Biodegradable – compostable plastics are not necessarily biobased or from biological feedstocks
 - End-of-life – what happens to product after use when ultimately disposed
- **BIOPLASTICS** is used to embrace both these classes of plastics

BIOBASED/BIOMASS BASED PLASTICS & PRODUCTS

- Organic (carbon based) materials that contain in whole or part biogenic (biological) carbon -- replacing petro/fossil carbon with bio/renewable carbon – beginning of life
- Offers the value proposition for a reduced carbon footprint
- **ASTM standard D6866** provides a test method to determine the biobased (carbon) content of the product



END-OF-LIFE OPTIONS FOR BIO PLASTICS & PRODUCTS

- What happens to product after use when it enters the waste stream
 - Design for biodegradability (in what disposal environment?)
 - Composting
 - COMPOSTABLE PLASTICS!
 - anaerobic digestion – for energy
 - Marine
 - soil
 - Recycling
 - Energy recovery (Collection, Buy back, mail back programs)
- Beware of misleading and deceptive biodegradability/compostability claims!



COMPOSTABLE PLASTICS

- Plastics that will **completely biodegrade** under composting environment (laboratory scale test method)
 - Completely assimilated/utilized by the microorganisms present in the composting disposal environment
 - Functions as “food” for the microorganisms present in the compost environment
- In addition:
 - Disintegrate in real world/large scale compost systems 90% + of material must pass through a 2mm sieve
 - pass ASTM standards for phyto and eco toxicity
 - Pass ASTM standards for regulated metal content
 - **ASTM D6400, D6868; ISO 17055, EN 13432**



Biodegradability – A misused and abused term

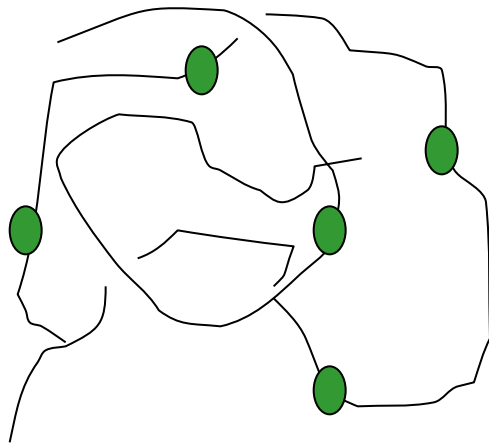
QUESTION

- Can microorganisms present in the **disposal environment** utilize/assimilate the plastic carbon substrate – the biotic process
- **What extent and in what time frame?**
- 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



What does Biodegradable Mean?

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



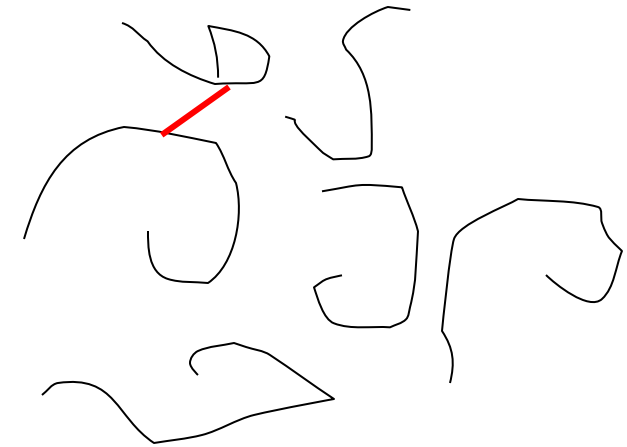
Polymer chains with susceptible linkages

Environment – soil, compost, waste water plant, marine



Hydrolytic
Oxidative
Enzymatic

STEP 1



Oligomers & polymer fragments

**Complete
microbial
assimilation**

defined time
frame, no
residues

STEP 2

CO₂ + H₂O + Cell biomass

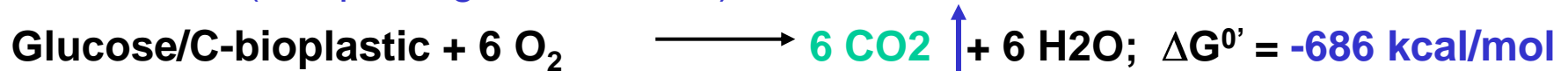
Biodegradation(Step 2): Only if all fragmented residues consumed by microorganisms as a food & energy source as measured by evolved CO₂ in defined time and disposal environment



Biodegradability/microbial utilization fundamentals

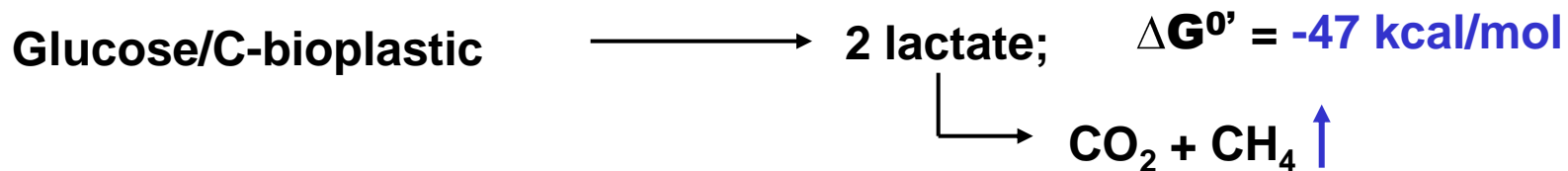
Microorganisms extract **chemical energy** for use in their life processes by the **aerobic oxidation** of glucose and other **utilizable substrates** – BIODEGRADABLE PLASTICS, food waste, paper, forest residues biological matter

AEROBIC (composting environment)



CO₂ is the quantitative measure of the ability of the microorganisms present in the disposal environment to utilize/assimilate the test C-bioplastic, which is the sole C-source available for the microorganisms – biodegradation or bioassimilation

ANAEROBIC



More Biodegradation/Bioassimilation Facts

The aerobic oxidation process (a highly specialized **cellular** phenomenon) requires the participation of three metabolically interrelated processes:

1. Tricarboxylic acid cycle (TCA cycle)
2. Electron transport
3. Oxidative phosphorylation

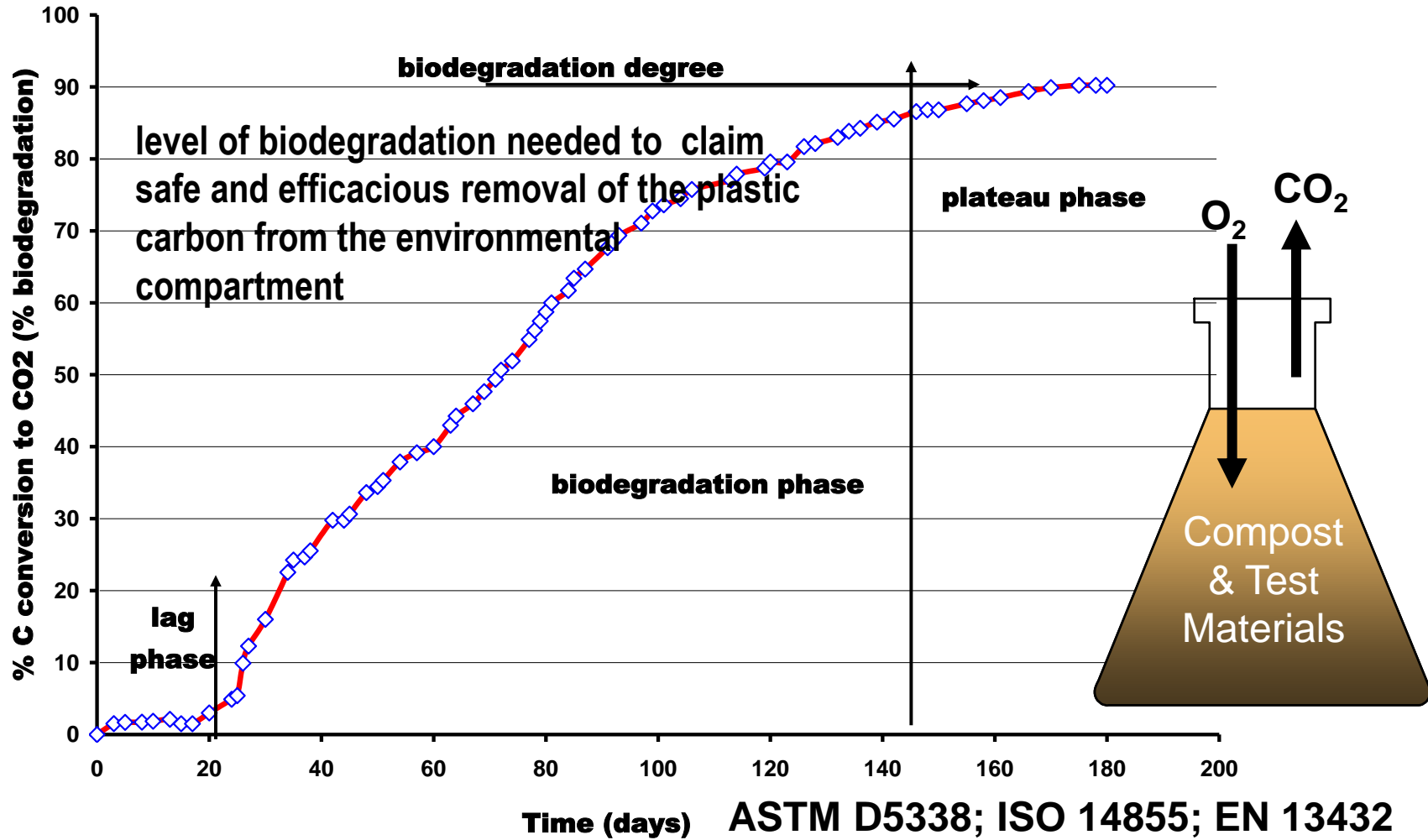
All of the processes take place **inside the cell**

For these processes to occur:

The substrates needs to be transported inside the cell

Thus, molecular weight, hydrophobic/hydrophilic balance, other molecular and structural features govern transport across cell membrane into the cell for utilization of the C-substrate.

Measuring biodegradability



Understanding ASTM Standards

ASTM develops several types of Standards – for the purpose of our discussion we will focus on the main ones:

Standard Specification -- these standards specify the requirements to be met and provide a pass/fail criteria

Standard Test method – this teaches how a test is to be precisely conducted, and how to report the results of the test

- A test method does not have a pass/fail criteria and the results from a ASTM test method could be positive or negative for example one could have zero percent biodegradation or 20% or 50% or 90% +
- Stating that a product passes an ASTM test method is **misleading and false** – a test method provides the numerical result of the test which could be zero or 100%

Standard Guide -- a compendium of information or series of options that does not recommend a specific course of action

Biodegradability under composting conditions

- **Specification Standards ASTM D6400, D6868 (coatings)**
- **Specification Standards EN 13432 (European Norm)**
- **Specification Standards ISO 17088 (International Standard)**

Biodegradability under marine conditions

- **Specification Standard D 7021**
-

Biodegradability Test Methods – ASTM Standards

- **Soil D5988**
- **Anaerobic digestors D 5511, ISO 15985**
 - **Biogas energy plant**
- **Accelerated landfill D 5526**
- **Guide to testing plastics that degrade in the environment by a combination of oxidation and biodegradation ASTM D 6954**

Must provide results from the test methods – could be zero or 50 or 100 percent --- generally not provided but claim of complete biodegradability made

Specification Standard for Compostable Plastic -- ASTM D6400

Microbial Utilization (D5338 test method):

- Demonstrate microbial utilization as measured by evolved carbon dioxide,
- 90% + carbon conversion to CO₂
- Same rate as natural materials Leaves, paper, grass & food scraps
- **Time** -- 180 days or less; if radiolabeled polymer is used 365 days or less



Specification Standard for Compostable Plastic ASTM D6400 (contd)

Disintegration

- ISO 16929 or ISO 20200 or under full scale regular industrial composting conditions for disintegration – 90% of material should have gone through a 2mm sieve
- ISO 16929, Plastics — Determination of the degree of disintegration of plastic materials under defined composting conditions in a pilot-scale test
- ISO 20200, Plastics — Determination of the degree of disintegration of plastic materials under simulated composting conditions in a laboratory-scale test
- ASTM STANDARDS UNDER DEVELOPMENT TO SIMULATE REAL WORLD NORTH AMERICA COMPOST PRACTISES



Specification Standard for Compostable Plastic --ASTM D6400 (contd)

Safety

- **No phytotoxicity (impacts on plants) using OECD Guide 208**
- **No ecotoxicity**
- **Regulated (heavy) metals less than 50% of EPA (USA, Canada) prescribed threshold**



Specification Standard ASTM D 6868

Standard Specification for Labeling of End Items that Incorporate Plastics and Polymers as Coatings or Additives with Paper and Other Substrates Designed to be Aerobically Composted in Municipal or Industrial Facilities

This specification covers end items that include plastics or polymers where plastic film/ sheet or polymers are incorporated (either through lamination, extrusion or mixing) to substrates and the entire end item is designed to be composted under aerobic conditions in municipal and industrial composting facilities, where thermophilic temperatures are achieved.



Problems with incomplete and partial biodegradation

- Thompson, R.C. et al. 2004. Lost at sea: Where is all the plastic? **Science 304, 838, 2004**
- plastic pieces can attract and hold hydrophobic elements like PCB and DDT up to one million times background levels. As a result, floating plastic is like a poison pill
 - From Algalita Marine Research Foundation – www.algalita.org/pelagic_plastic.html
- PCBs, DDE, and nonylphenols (NP) were detected in high concentrations in degraded polypropylene (PP) resin pellets collected from four Japanese coasts.
- Plastic residues function as a transport medium for toxic chemicals in the marine environment.
 - Takada et al Environ. Sci. Technol. 2001, 35, 318-324
 - Blight, L.K. & A.E. Burger. 1997. Occurrence of plastic particles in seabirds from the Eastern North Pacific. Mar. Poll. Bull. 34:323-325
 - Phil. Trans. Royal. Soc. (Biology) July 27, 2009; 364

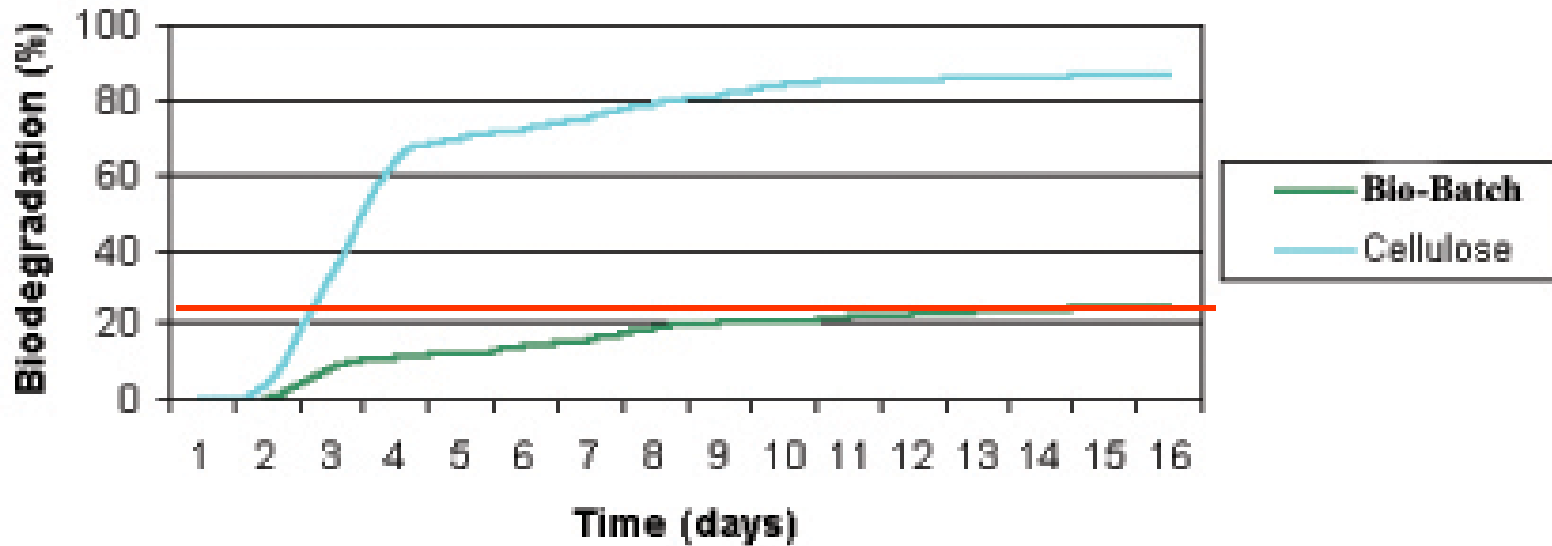
Sorting through facts, hypes, claims (misleading)

GREEN WASHING



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”



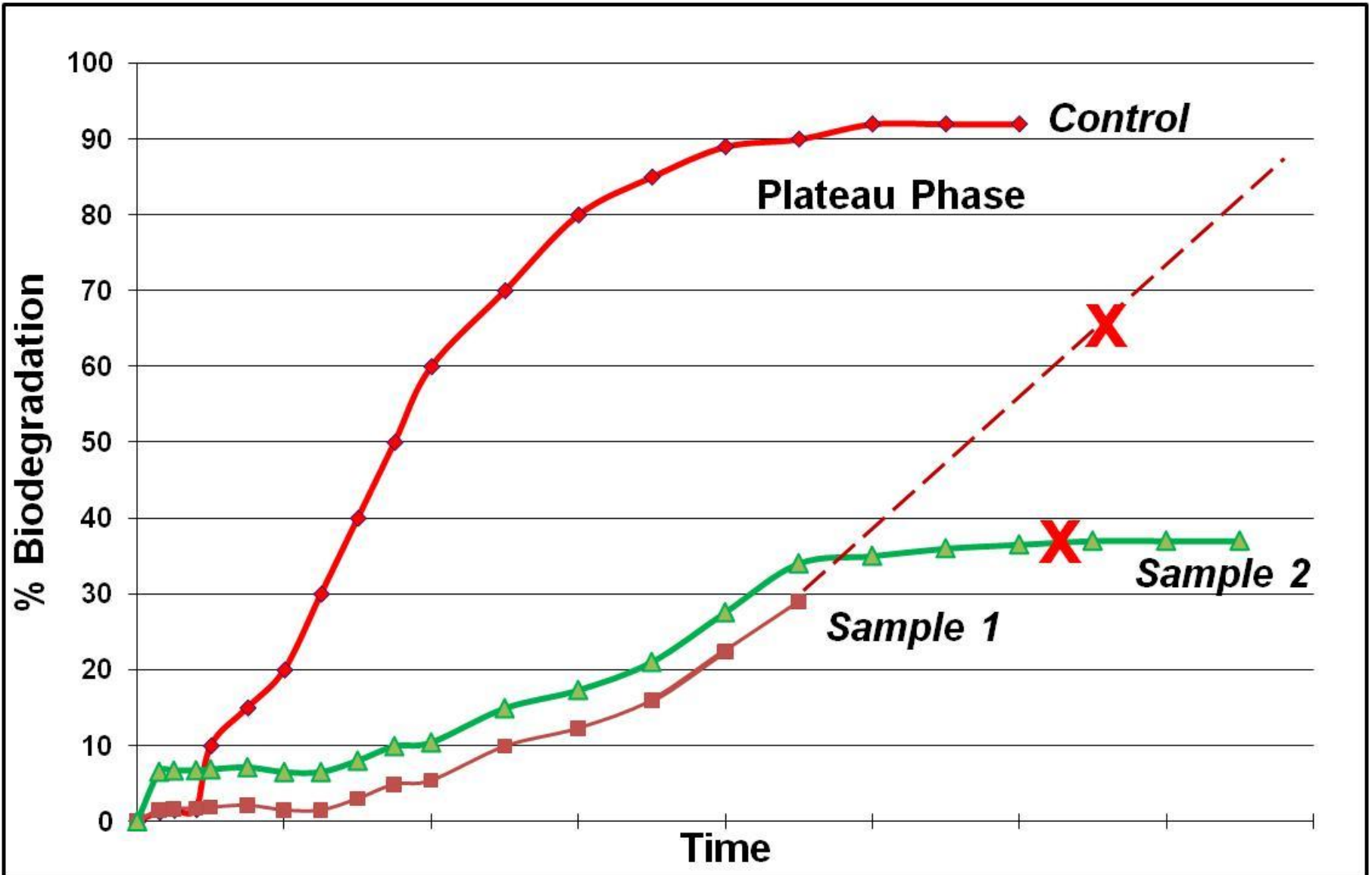
The 50% Bio-Batch film did not degrade as completely or as quickly as the cellulose. At the end of the test, 19% of the film had degraded.

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!



MISLEADING BIODEGRADABILITY CLAIMS



MISLEADING CLAIMS – UNSUPPORTED BY DATA

Oxo-biodegradable polyethylene (PE) film claims –

*“Combined with an oxo-biodegradable proprietary application method to produce films for bags. This product, when discarded in soil in the presence of microorganisms, moisture, and oxygen, **biodegrades, decomposing into simple materials found in nature.** Completely breakdown in a landfill environment in 12-24 months leaving no residue or harmful toxins and have a shelf life of 2 years”*

No scientific substantiation showing complete microbial utilization using established standard test methods

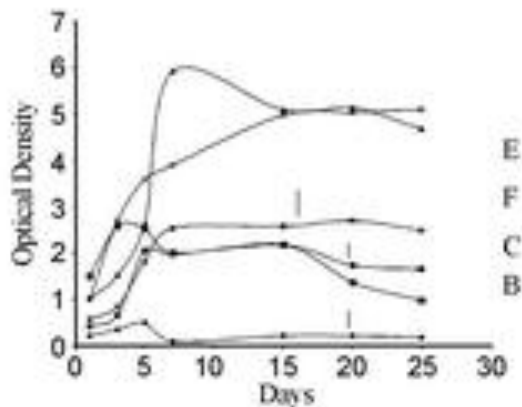
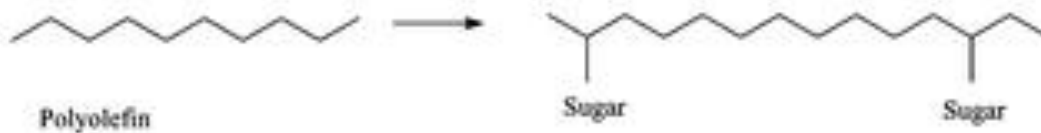
BIODEGRADABILITY CLAIMS

- **Chem. Commun.**, 2002, (23), 2884 - 2885

- 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.



Increase in rates of biodegradation for sugar linked polystyrene

weight loss of only 2-12%,

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



Peer Journal Publications

- 2009 paper by Odeja et al titled “Abiotic and Biotic degradation of oxo-biodegradable polyethylenes
- The oxo-biodegradable PE samples that were abiotically degraded in natural and saturated humidity for one year were biodegraded in a mixture of soil:compost:perlite (1:1:2) at 58 °C for three months.
- The percent biodegradability as measured by evolved CO₂ was 3.61% (abiotic natural humidity) and 5.70% (abiotic saturated humidity).
- The percent biodegradability for samples weathered for one year in PP envelopes in compost at 58 °C was 12.4%, and at 25 °C was 5.4% after three months.

CLAIM

Oxo-biodegradable PE will completely (100%) in soil, compost, landfill in 9 months to 5 years

Similarly PP (polypropylene), PVC (polyvinyl chloride), PET (polyethylene terephthalate) will 100% biodegrade in 9 months to 5 years



Biodegradability Factoids

- An independent study commissioned by the State of California's Waste Management Board with a California public university showed that the "oxo-biodegradable" bags on the market showed no biodegradation ("Performance Evaluation of Environmentally Degradable Plastic Packaging and Disposable Service Ware," California Integrated Waste Management Board (CIWMB) Publications)
 - <http://www.ciwmb.ca.gov/Publications/Plastics/43208001.pdf> (June 2007).
- This study, and the proliferation of unsubstantiated wild claims on biodegradability forced the State of California to put in place laws:
 - State of California passed law AB 1972 that no claims of biodegradability should be made unless it meets ASTM D6400 & city of San Francisco
 - AB 2071 authorize a city, a county, or the state to impose civil liability, in specified amounts, for violations of the above provisions



GREEN WASHING

**NAD (National Advertising Division of the Council of Better Business Bureaus)
EXAMINES ADVERTISING FOR GP PLASTICS CORP.**

‘POLYGREEN’ PLASTIC BAGS

NAD Recommends Marketer Modify, Discontinue Certain ‘Green’ Marketing Claims

NAD recommended the following claims be discontinued:

- *Enviroware is formulated to degrade in months when buried or discarded in a landfill*
- *Enviroware cutlery, straws, hinged containers, plates, bowls and trays are 100% biodegradable and come with a certificate of biodegradability.*

Federal Trade Commission (FTC) recently brought action against three companies for scientifically unsubstantiated biodegradability claims that their products biodegrade within a reasonably short period of time (landfill

US Federal procurement requires biodegradability claims to be substantiated by ASTM D6400 specification standard



TAKE HOME MESSAGE

Biodegradability is an end-of-life option for single use disposable, packaging and consumer plastics that harnesses microbes to completely utilize the carbon substrate and remove it from the environmental -- entering into the microbial food chain.

However, biodegradability must be defined by:

- The disposal system – composting, anaerobic digester, soil, marine**
- Time required for complete microbial utilization in the selected disposal environment – short defined time frame, and in the case of composting the time frame is defined as 180 days or less**
- Complete utilization of the substrate carbon by the microorganisms as measured by the evolved CO₂ (aerobic) and CO₂ + CH₄ (anaerobic) leaving no residues**

Degradability, partial biodegradability, or will eventually biodegrade is not an option! – serious health and environmental consequences can occur as documented in literature



TAKE HOME MESSAGE (Contd)

Specification Standards sets specific requirements to be met for pass/fail criteria using ASTM test method

- ASTM D6400 specification standard using ASTM D5388
- ASTM D6868 specification standard using D5338 and D6400
- Set up for composting and marine environment only

Test methods teaches how to conduct the test and report the results

- No pass/fail criteria
- Claims using test method as proof of % biodegradability is misleading and false
- Must provide data showing percent biodegradation as a function of time in days
- 10-20 % biodegradation curve at the plateau (levels off) represents little or no biodegradation
- Extrapolation of data to make claims is specifically prohibited in the Standard

