

Biodegradable Plastics

by Emma Seigel, with Lisa Barlow

Introduction

Biodegradable products, including packaging, appear to be a good alternative to conventional plastics. In an ideal situation, it appears that the cons of biodegradable plastics far outweigh those of conventional plastics. However, in a practical situation, biodegradables may or may not be the best solution depending on numerous factors such as how the products are used, how they are disposed of, and how the waste is managed. The history of biodegradable plastic products started out badly. The first generation of degradable plastics, polyolefin-starch materials, did not degrade as claimed.¹ Over a 16 month period in the early 1990s, 48 separate legal actions were taken for misleading or deceitful environmental advertising. The highest number these actions were on claims of biodegradable plastics and on the use of the terms “biodegradable” and “recyclable.”² Since that time, universal standards have been developed by the American Society for Testing and Materials (ASTM), new materials have been introduced, and a compostable logo has been developed to guide consumers in their decision-making. The implementation of disposal and treatment systems for biodegradable and compostable plastic products creates unique challenges. Careful consideration of products and implementation is important prior to program initiation.

The University of Colorado is considering biodegradable alternatives to conventional plastics in their Grab-n-Go venues. Lauren Heising, Kerry Paterson, and other members of Dining Services at CU have requested research and information on biodegradable packaging in order to make informed purchasing decisions and make progress in their commitment to a sustainable future.

Objective

The objective of this project is to review the current standards for biodegradable and compostable plastic products as they relate to food packaging and bags. Consideration of the effects that biodegradables have on conventional recycling streams, landfills, and waste disposal systems is crucial when deciding on packaging options. Like many Universities reaching for more sustainable practices, CU is interested in the status of compostable plastics from renewable feedstocks. Overall, biodegradable alternatives are not an easy solution to a waste problem; the best are certified compostable and are intended to be composted in municipal facilities. The information is presented in the following order: terminology, compostability, landfilling, and biodegradable/compostable bags.

Part 1: Terminology: Degradable, Biodegradable, Compostable, and Biobased Plastics

The term “biodegradable plastic” lends itself to visions of a container or bag that will breakdown quickly to natural earthly elements and compounds if left to its own devices.

¹ Narayan and Pettigrew. 1999

² Narayan and Pettigrew. 1999

However, the terms “degradable”, “biodegradable” and “compostable” have different meanings. The following terms are found in a compilation of definitions from the American Society for Testing and Materials/Institute for Standards Research (ASTM/ISR) and the Comite European de Normalisation (CEN) by Riggle,³ and in Narayan and Pettigrew.⁴

Degradation: ... “an irreversible process leading to a significant change of the structure of a material, typically characterized by a loss of properties (e.g. integrity, molecular weight or structure, mechanical strength) and/or fragmentation. Degradation is affected by environmental conditions and proceeds over a period of time comprising one or more steps.”

Degradable Plastic: “A plastic designed to undergo significant change in its chemical structure under specific environmental conditions, resulting in a loss of some properties (as above) that may be measured by standard methods appropriate to the plastic and the application.” There are no requirements that these plastics have to degrade from natural processes or any other criteria. A residue is always left behind from degradable plastics. Degradable plastics are further categorized based on the method of degradation.

Biodegradable Plastic: “A degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae.” Biodegradable plastics must biodegrade in specific environments such as soil, compost, or marine environments. There is no regulation addressing toxic residue, and no specific time requirement for degradation. Numerous factors affect the biodegrading process, including composition of materials and disposal environment. In order for plastics to biodegrade they go through a two-step process as shown in figures 1 and 2.

Other types of degradable plastic are named for their process of degradation.

Photodegradable Plastic: “... degradation results from the action of natural daylight.”

Oxidatively Degradable Plastic: “...degradation results from oxidation.”

Hydrolytically Degradable Plastic: “...degradation results from hydrolysis.” (e.g. breakdown in water)

³ Riggle, David. 1998.

⁴ Narayan and Pettigrew. 1999

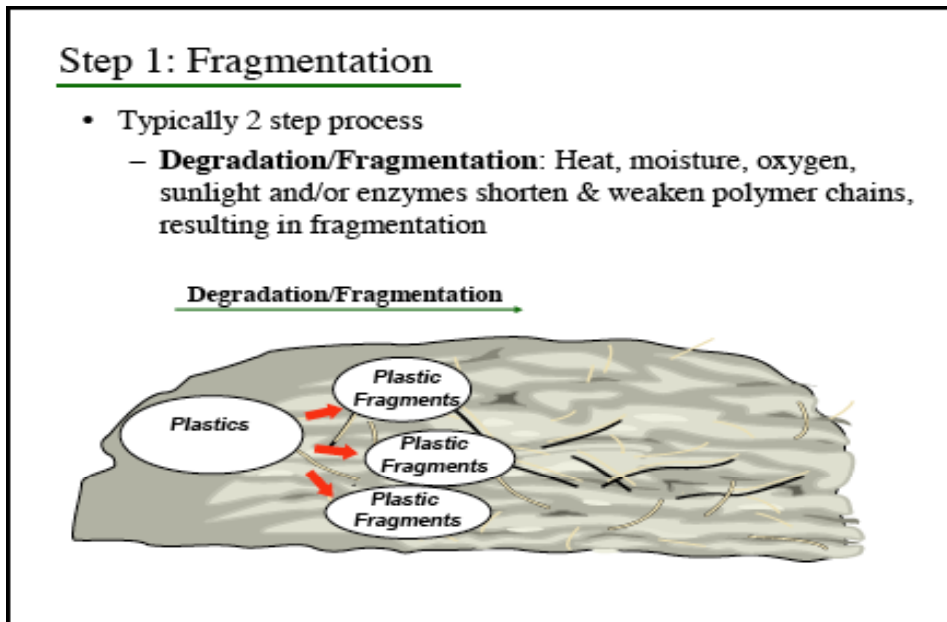


Figure 1. This figure shows the first step of biodegradation. Depending on the type of biodegradation taking place, this process is initiated by heat, moisture, microbial enzymes, or other environmental factors.⁵

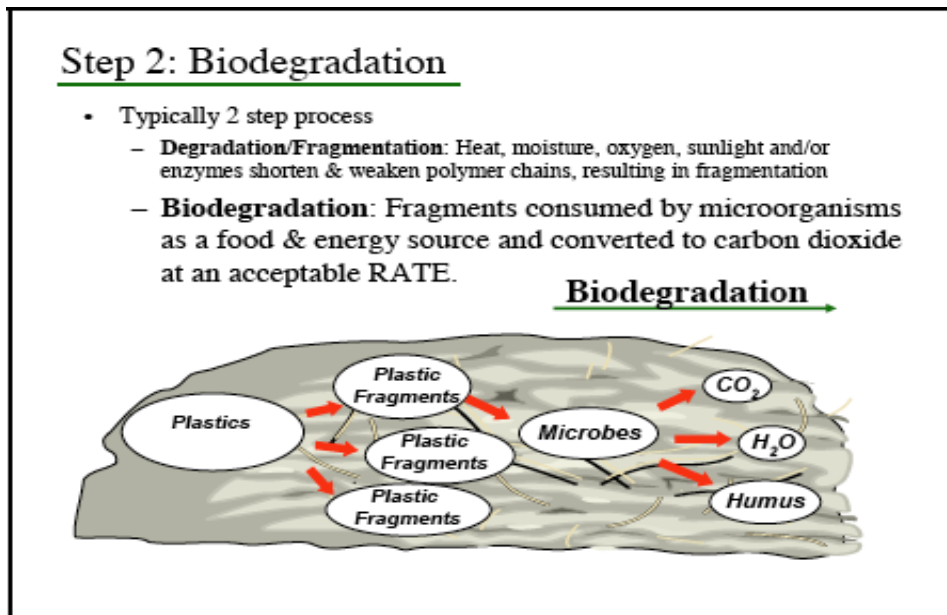


Figure 2. This figure shows the second step which takes place when the short carbon chains pass through the cell walls of the bacteria or microbes and are used as an energy source. This is biodegradation, when the carbon chains are used as a food source and are converted into water, biomass, and carbon dioxide or methane.⁶

⁵ Confused by the term biodegradable and biobased. 2006.

⁶ Confused by the term biodegradable and biobased. 2006.

Deceptive claims about biodegradability have risen to the level of notice by the Federal Trade Administration (FTC). The FTC Guide to Environmental Marketing Claims states the following:⁷

“It is deceptive to misrepresent, directly or by implication, that a product or package is degradable, biodegradable, or photodegradable. An unqualified claim that a product or package is degradable, biodegradable or photo-degradable should be substantiated by competent and reliable scientific evidence that the entire product or package will completely break down and return to nature, that is, decompose into elements found in nature within a reasonable short period of time after customary disposal. Claims of degradability, biodegradability or photodegradability should be qualified to the extent necessary to avoid consumer deception about: (a) the product or package's ability to degrade in the environment where it is customarily disposed; and (b) the rate and extent of degradation.”

Compostable: “Capable of undergoing biological decomposition in a compost site as part of an available program, such that the material is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds and biomass, at a rate consistent with known compostable materials.”

Compostable Plastic: “A plastic that undergoes biological degradation during composting to yield carbon dioxide, water, inorganic compounds and biomass at a rate consistent with other known compostable materials and leaves no visually distinguishable or toxic residues.” Toxic residues important for compost quality include heavy metal content and ecotoxins.

The FTC’s position on compostability is similar, in that claims of compostability should be substantiated by competent and reliable scientific evidence, and that materials will break down into or become part of soil conditioning material or mulch in a safe and timely manner. The FTC recognizes confusion about compostable claims that require, but do not specify, the need for municipal or commercial composting facilities:

The Compostable guide is amended to clarify that an unqualified compostable claim can be made if a product is compostable in a home compost pile or device, even if municipal or institutional composting facilities are not locally available. This is because consumers are likely to perceive claims of compostability to mean that a product may be composted in a home compost pile or device.⁸

In addition to the definitions above, some plastics available on the market are “biologically based”, or “biobased”. “Biobased” refers to a product’s materials content, not its degradability. “Biobased” is used to describe industrial or commercial products

⁷ FTC Environmental Marketing Claims. 1999.

⁸ Federal Trade Commission. 1998.

that are not developed for food or feed, according to the federal government.⁹ The following definition of a biobased material comes from ASTM.¹⁰

Biobased: “an organic material in which carbon is derived from a renewable resource via biological processes. Biobased materials include all plant and animal mass derived from CO₂ recently fixed via photosynthesis, per definition of a renewable resource.”

Products defined as “biobased” can vary in content from 100% biologically based to a combination of petroleum and biologically based materials. Furthermore, even if a product is 100% biologically based, it is not necessarily biodegradable or compostable. ASTM has created standards for testing biologically based content using radiocarbon and isotope mass spectrometry analysis (ASTM D6866), and for compostable plastics (ASTM D6400).¹¹

The Biodegradable Products Institute

The Biodegradable Products Institute (BPI) is an association of individuals and groups from government, industry and academia that promotes the use, recycling and composting of biodegradable polymeric materials.¹² BPI is the leading US source of information and publications about biodegradable products. It provides a database of information and materials that meet ASTM D6400 or D6868 standards, and serves as an industry watchdog on claims of biodegradability.^{13 14} An overview of the publications available from BPI shows that leaders in this field want an industry standard of certified products that are 1) fully compostable in municipal and commercial composting operations 2) independently tested and 3) clearly labeled as such. In 2005, BPI joined with the US Composting Council (USCC) in launching the Compostable Logo (Figure 3), which identifies products that meet ASTM compostability standards and can be safely composted in municipal and commercial composting operations.¹⁵



Figure 3. label for compostable plastic products.

⁹ Greening the Government, 2000

¹⁰ in Confused by the terms biodegradable and biobased. 2006

¹¹ Confused by the terms biodegradable and biobased. 2006

¹² Biodegradable Products Institute. 2007.

¹³ Biodegradable Products Institute. 2007.

¹⁴ What's the story. 2007.

¹⁵ Compostable Logo Fact Sheet. 2005

Part 2: ASTM D6400 Compostable Standards

ASTM D 6400, the Standard Specification for Compostable Plastics, establishes specifications for proper testing and labeling of compostable plastics. The standard tests whether plastics and plastic products will compost satisfactorily, including biodegrading at a rate comparable to natural compostable materials. Results of the standards testing activities can be purchased from ASTM. The following review is based on Narayan and Mojo.¹⁶

In order to be considered compostable, all materials must meet all three of the following criteria. ASTM has developed three separate tests based on these criteria.¹⁷

- **Biodegrade-** Be converted to carbon dioxide, water, and biomass at same rate as Kraft paper and other certified compostable materials.
- **Disintegrate-** Not be visible or need to be screened out after composting.
- **Be Safe for the Environment (no ecotoxicity)-** Degradation must not cause any harmful byproducts and the compost must be able to support plant growth. The only reliable measure of non-toxicity is the complete conversion of carbon to carbon dioxide or methane.

Biodegradability tests are done using ASTM D5338 procedures, which call for placing the sample plastic and a measured amount of active compost in sealed flasks with gas exchange capability. Blank and control materials are also placed in sealed flasks. Temperature (58⁰C, 136⁰F), moisture and oxygen are maintained in the flasks to obtain optimal microbial activity. The biodegradation is determined by measuring the amount of carbon dioxide produced from the degrading plastic over a 6 month period.¹⁸ In order to determine biodegradability, analysts take the measured level of CO₂ produced and calculate the amount of carbon converted to carbon dioxide. From this, the percentage of the material that is mineralized (converted to CO₂) is calculated. The criteria for passing the biodegradability test, according to requirements found in ASTM D6400 is that the material exceed 60 percent conversion to CO₂ for a homopolymer, and 90 percent conversion for polymer blends and copolymers with additives. The reference material is cellulose. The 60% is the conversion rate was established based on the conversion rate of of kraft paper, which was the reference material in the original investigations.¹⁹

Disintegration of a material is measured by sifting through the residue left behind after the biodegradation test. The product passes the disintegration test if less than 10 percent of the residue material remains on a 2 mm screen after twelve weeks. The disintegration test serves the purpose of proving that any non-degraded pieces left over would be indistinguishable in finished compost.

Eco-toxicity is determined by measuring plant growth and germination from soils with 0% (reference) to 1 to 10% mixes of soil and compost. If plant growth and germination from soils with biodegraded compost content are significantly lower than

¹⁶ Narayan and Mojo. 2002

¹⁷ Narayan and Mojo. 2002

¹⁸ Riggle. 1998

¹⁹ Mojo. Personal communication. 2007

plants from the control soil, then the product will not pass the eco-toxicity test. In addition to these three tests, the plastic material must undergo chemical and metals testing to ensure the product will not exceed pollutant limits.

In all cases, a product that meets ASTM standards and is awarded the Compostable Logo is intended for municipal or commercial compost operations, and not for backyard compost bins.

Part 3: Biodegradable and Compostable Plastics in Landfills

Plastics will biodegrade when they are broken down by other living organisms and thus recycled back into the system. This process occurs best in aerobic environments, where oxygen can help break the molecules apart. Most landfills are designed to be arid tombs, and biodegradation is slow and anaerobic because landfills are compacted so tightly by layers of waste and are covered daily. In an environment such as a landfill, any biodegradation, whether it is food, paper, or biodegradable plastic, will degrade at a very slow rate, if at all. Many biodegradable items, bags for example, are designed so that they oxidize with the help of sunlight over a period of time or get dissolved in water. This will not likely occur in a landfill environment. Furthermore, the anaerobic microorganisms that thrive in landfills release methane, a greenhouse gas that contributes to global warming.

In the past and still currently, there are “biodegradable” plastic products available that do not properly break down (see, e.g. bags section of this report). This often has to do with the fact that the polymers are unrecognizable to enzymes in microbes that facilitate biodegradation. For biodegradable materials that meet ASTM standards, every organic compound used at 1% or higher must be able to biodegrade.²⁰ In addition, an Australian survey of landfill operations found that wind-blown plastic bags are a major litter issue around landfill sites.²¹ As these wind-blown bags are not exposed to microbial activity, biodegradable bags have little advantage over conventional plastic bags in solving this problem. Overall, biodegradable and degradable plastics will not biodegrade effectively in a landfill site.

Part 4: Biodegradable Bags

What about Biodegradable Bags?

Biodegradable shopping bags are made of polymers that degrade, or decompose, when exposed to air, water, or sunlight. Currently, CU Dining Services is promoting their use of biodegradable bags from Grab-n-Go's. There are three main types of biodegradable bags:

- 1) The original biodegradable bags, still found today, are made from resins containing starches, polyethylene, and heavy metals such as cadmium, lead, and beryllium.

²⁰ Mojo, personal communication, 2007

²¹ Plastic Shopping Bags in Australia. 2002

- 2) A second type has been invented using starches combined with biodegradable polymers such as polylactic acid (PLA) or EcoFlex. These bags meet ASTM compostable standards, while others do not.²²
- 3) Oxo-Biodegradable bags use Totally Degradable Plastics Additives (TDPA™) to stimulate the break-down of polymers and thus speed up the biodegradation process of conventional plastics.²³

Piazanos uses the third type of biodegradable bag probably because, not surprisingly, purchasers believed the advertisement on the product. In reality, the EPI Oxo-Biodegradable bag is labeled as a no. 4 (conventional) plastic bag, and carries no information on meeting ASTM standards. Testing of the EPI Oxo-Biodegradable bags, as reported by the Biodegradable Products Institute,²⁴ found that the presence of moisture or humidity stops or delays the onset of oxidation, which means that composting slows down the degradation of these bags. In addition, tests found significant levels of cobalt, a trace metal that is not regulated in the United States, but is monitored in EPA Superfund sites. Furthermore, there is concern that oxo-biodegradable bags can contaminate conventional plastics because the active chemical in the bags works to weaken and destabilize plastic.²⁵ The global extent of the controversy on biodegradable plastic bags is demonstrated by the following points from a report to the Australia Department of Environment and Water Resources. These issues are important when considering the use of biodegradable bags in any region of the world.²⁶

- Bags ingested by marine organisms, when mistaken for jellyfish or other translucent organisms, will not degrade in the organism's gut. In this sense, biodegradable bags are no better than conventional plastic bags.
- Bag littering could easily increase because the general population believes that biodegradable bags pose no harm to the environment and will disappear quickly. When biodegradable bags are blown into trees, and microbes are not available, breakdown can take years.
- Biodegradable bags are a contaminant in traditional plastic bag recycling. Mixing biodegradable bags in recycling systems with conventional plastic bags creates a sorting nightmare and can render entire batches of recyclable plastic useless.

The Biodegradable Products Institute is working toward a goal that all biodegradable plastic bags should meet compostable standards. This goal serves a dual purpose, as compostable bags are the optimal way to collect and divert food, yard clippings, and other organics away from landfills and into composting programs. A BPI Position Paper on biodegradable plastic bags urges communities to consider the following before converting from conventional plastic bags: "If your community does not have the collection system in place to collect "compostables" or "biodegradables", then it does not make sense to mandate this alternative, as there is no place for the to be taken except the

²² Narayan and Mojo. 2002

²³ EPI-Global. 2005.

²⁴ BPI assessment of oxo-degradable films. 2007.

²⁵ *in* Fyfe, Melissa. 2004.

²⁶ Biodegradable Plastics - Developments and Environmental Impacts. 2002.

landfill. Rather, communities should focus on developing strategies to recycle traditional plastic bags.”²⁷

Recommendations

The biodegradability of “biodegradable” plastics has improved since initial offerings, however, there is still a way to go before the ideal of a market of uniformly fully compostable plastics can be realized, and consumers still must educate themselves on the true meaning of the words “biodegradable” and “compostable” on products. In addition, none of the currently certified compostable products are approved for back-yard compost bins. This means that compostable plastics must be collected and transferred to, in CU’s case, a commercial composting facility. Pre- and post-consumer food waste from some dining halls on campus is currently being collected for commercial compost, and properly certified and labeled compostable bags are an advantage for these collections. At CU Boulder, there is no current infrastructure to collect compostables from students. Implementation of a compostable collections strategy for residence hall students and for outdoor campus receptacles is not on the immediate horizon. Therefore, there is no advantage for Dining Services or the CU campus to adopt biodegradable or compostable plastics in Grab-n-Go packaging. The current oxo-biodegradable Grab-n-Go bags do not meet biodegradable or compostable standards and offer no advantage. Furthermore, conventional plastic bags are not collected at CU for recycling. Given these facts, and the observation that the plastic bags promote a “single toss” behavior into the trash can without thought for sorting recyclables, we propose that CU Dining Services look to alternatives to single-use bags.

Alternatives to Single Use Bags

The focus of our class has been to formulate and promote short-term and long-term sustainable techniques for Dining Services. As explained in this report, biodegradable bags are not a viable current solution here at the University of Colorado. Rather we suggest a number of alternative solutions to single use bags in Grab-n-Go locations.

1. Canvas or other reusable bags for those students who use Grab-n-Go locations significantly reduce the use of single use bags.
2. Moving bags to the front of the line at Grab-n-Go locations so cashiers could regulate the use of the bags and encourage students to use alternatives such as canvas or put the item in their own bags.
3. A nickel charge when a customer requests a bag, where proceeds go to funding education, outreach, and infrastructure.
4. Implement a “nickel back” program like that at Wild Oats Stores. This rewards students by giving them the opportunity to conserve and give back to the community and the environmental movement.

“Nickel Back” Program

The “Nickel Back” program is a way to encourage students to bring a bag of their own or choose not to use a bag at the Grab-n-Go location. When a student chooses not to take a new plastic bag, they are rewarded with a wooden nickel. The student can then

²⁷ Macy and Mojo. 2007.

choose to deposit the nickel in one of several banks that represent different non-profit organizations in and around Boulder. The “Nickel Back” program would connect students to their community by making recycling and reuse something that would benefit the campus and local community as well as the environment.

References

- Biodegradable Plastics - Developments and Environmental Impacts*. Nolan-ITU Pty Ltd and ExcelPlas Australia. Report prepared for Australia Department of Environment and Water Resources. October 2002.
<http://www.environment.gov.au/settlements/publications/waste/degradables/biodegradable/index.html>
- Biodegradable Products Institute 331 W. 57th St. Suite 415, New York, N.Y. USA
<http://www.bpiworld.org/BPI-Public/About.html>, www.BPIworld.com. 2007.
- BPI assessment of oxo-degradable films*. Biodegradable Products Institute. Personal communication, Steve Mojo. May, 2007. e-mail: info@bpiworld.org
- Compostable Logo Fact Sheet*. Biodegradable Products Institute. 2005.
<http://www.bpiworld.org/Files/Article/ArtwQY8QK.pdf>
- Confused by the term biodegradable and biobased*. Biodegradable Products Institute.
<http://www.bpiworld.org/Files/Article/Art7OPeSJ.pdf>. 2006.
- EPI-Global. <http://www.epi-global.com/en/Index-e.htm>. 2005
- Federal Trade Commission. *Guide to Environmental Marketing Claims*. 1999
<http://www.ftc.gov/bcp/conline/pubs/buspubs/epaclaims.shtm>
- Federal Trade Commission 16 CFR PART 260 Guides for the use of Environmental Marketing Claims*. Federal Trade Commission. 1998.
<http://www.ftc.gov/os/1998/04/greengui.fr1.htm>
- Fyfe, Melissa. Degradable Bags can last years. *The Age*. June 29, 2004.
<http://www.theage.com.au/articles/2004/06/28/1088392600296.html?oneclick=true>
- Greening the Government Explored at Bio-Based Products Seminar*. ASTM Standardization News, November 2000. http://www.astm.org/cgi-bin/SoftCart.exe/SNEWS/NOVEMBER_2000/nov_bio.html?L+mystore+xnhf8640
- Macy, Jack, and Mojo, Steve. *Do "biodegradable" plastic bags make sense for your community?* Biodegradable Products Institute. Personal communication, Steve Mojo. May, 2007. e-mail: info@bpiworld.org
- Mojo, Steve, personal communication, May, 2007. e-mail: info@bpiworld.org

- Narayan, Ramani, and Pettigrew, Charles, ASTM standards define and grow biodegradable plastics. ASTM Standards News, December 1999, <http://www.bpiworld.org/Files/Article/ArtNRIC7b.pdf>.
- Narayan, Ramani, and Mojo, Steve, Summary of ASTM D6400 Test Method and Specifications and Correlation of Test Methods to Real World Composting Results, International Biodegradable Products Institute, 2002. <http://www.bpiworld.org/BPI-Public/News/Article.html>
- Plastic Shopping Bags in Australia. National Plastic Bags Working Group Report to the National Packaging Covenant Council. 6 December 2002. <http://www.environment.gov.au/settlements/publications/waste/plastic-bags/pubs/report-2002.pdf>
- Riggle, David. *Moving towards consensus of degradable Plastics*. Biocycle, March 1998 accessed at <http://www.bpiworld.org/Files/Article/Artzu9gsH.pdf>.
- What's the story on degradable polystyrene?* Biodegradable Products Institute Position Paper. May 2007. <http://www.bpiworld.org/Files/Article/ArtfwpHn2.pdf>
- (Could not access for lack of membership) Greer, Diane. *Plastic from Plants, Not Petroleum Part II*. Biocycle. June 2006 v. 47 no. 6 p. 33. article description states inclusion of lifecycle analysis and industry outlook. <http://www.jgpress.com/biocycle.htm>