BIOPLASTICS SIMPLIFIED:
ATTRIBUTES OF BIOBASED AND BIODEGRADABLE PLASTICS
FALL 2020
The PLASTICS Bioplastics Division would like to thank the following individuals for reviewing this document:

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The reviewers provided a review of this document but did not have final approval of the document and do not specifically endorse the document. This page acknowledges their contributions.

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In this report, the term biodegradable may be used to discuss polymers. Biodegradable properties vary depending on many factors specific to the finished product, constituent polymers, and intended conditions of use and disposition. Any claim that a finished product is biodegradable or compostable (e.g., home/industrial compostable, marine/soil biodegradable, or anaerobic digestible) must be supported by relevant, competent, and reliable scientific evidence. PLASTICS has not independently examined each claim and has relied on thirdparty information.
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The term “bioplastics” describes a wide range of materials. This paper discusses the growing field of bioplastics, and how material innovations can offer environmental advantages.

The globally accepted definition developed by the industry of “bioplastics” is “biobased and/or in some way biodegradable.” A biobased bioplastic has some or all of its carbon produced from a renewable source. Biodegradable bioplastics are those that degrade into biomass, carbon dioxide (CO2) and water through biological action in a defined environment and in a defined timescale. These defined environments include composting, anaerobic digestion, and marine and soil environments. Terms such as “biobased”, “biodegradable”, etc. have more detailed scientific and legal definitions that will be expanded upon in later sections of this document.

In this fast-evolving landscape, it is important to note that company specific claims that products include biobased content and/or are biodegradable must be made carefully, with due consideration of relevant scientific standards, as well as applicable federal and state regulations and guidance. Particular attention should be given to the U.S. Federal Trade Commission’s (FTC) Guides for the Use of Environmental Marketing Claims (or Green Guides, at 16 C.F.R. Part 260), which clarify the FTC’s position on “biodegradability”, “compostability”, and other degradability claims, among others. States and other localities may have additional requirements for labeling and marketing bioplastics. Companies making biobased and/or biodegradable claims must ensure they have competent and reliable scientific evidence for the origin or degradability claims for their products. Qualifications may be necessary to assure that customers understand the claims and, if degradability is the claim, the conditions in which degradation can be expected to take place.'
BIOPластик: частично или полностью биобазированный и/or биоразлагаемый
A bioplastic that is biobased has some or all of its carbon derived from a renewable source. “Renewable” is defined as a resource that is inexhaustible or readily replaced. The biobased content may be the polymer, filler, or an additive. A material is also considered to be biobased if produced in yeast, bacteria, or algae grown and cultivated with biobased feedstocks such as sugar or lipids as long as the source of carbon within them is partially or wholly from non-fossil sourced (e.g., not feedstocks that are petroleum or natural gas.)

Presently, most biobased bioplastics are sourced from plant-based raw materials coming from traditional crops like corn and sugar cane. However, research is ongoing to move to second and third generation feedstocks including agricultural, forest, and municipal waste, as well as algae and other biobased feedstocks not coming from food sources. Bioplastics are increasingly being derived from these non-food sources through cellulosic sugars and triglycerides contained within them.

The biobased content of a bioplastic can be reported in several ways. The most common methods are as the percent of the weight that is renewable resource content and the percent biobased carbon content in the bioplastic. This measurement is the basis for certification under the USDA BioPreferred Program, a federal program that promotes the purchase and use of biobased products via mandatory federal purchasing requirements, and a voluntary labeling initiative for biobased products, similar to the USDA Organic Program. The percent biobased carbon content refers specifically to organic carbon and is measured using the ASTM D686 test method specification. For further discussions on the differences between biobased carbon content and renewable resource content, please refer to the PLASTICS Bioplastics Division’s “Understanding Biobased Carbon Content.”

Potential benefits of biobased bioplastics are numerous. The specific benefits of a particular bioplastic from an overall environmental standpoint should be determined through a life cycle assessment (LCA) or other data gathering and analysis tool that broadly assesses environmental benefits and burdens.
Bioplastics produced from biobased polymers can perform the same as the same polymer produced from a fossil source. Examples of commonly non-biobased polymers with partially or fully biobased equivalents are: polyethylene (PE), polyethylene terephthalate (PET), and several types of polyamides. These bioplastics have the same property and processing characteristics as their fossil-sourced equivalents because those properties are driven by the polymer chemical structure rather than by the source of the carbon. They are also sometimes called “drop-in replacements” for fossil-sourced equivalents.

Biobased bioplastics typically lead to a reduction in the material’s carbon footprint relative to fossil-based equivalents. As illustrated in Figure 1, this happens because the biobased carbon content is typically CO2 captured from the atmosphere through plant growth. This also leads to reduction of the GWP associated with the biobased bioplastic.

Biobased plastics that are not compostable or otherwise biodegradable are ideal for applications such as durable goods and items that are highly recycled. A soda or bottle made from biobased PET or PE can be recovered and recycled through the standard recycling infrastructure without any issues.

When plants photosynthesize, they absorb carbon dioxide from the atmosphere and expire oxygen that we breathe. The carbon is used in the plant’s cells to make polysaccharides -

When those polysaccharides are converted into plastics, like polyethylene, this carbon is further sequestered away from the atmosphere.
Figure 1. Biobased Polyethylene as an example of a biobased biopolymer which is recyclable.

Fossil-based feedstocks like petroleum or natural gas are a rich source to many produce chemical building blocks.

These can be used to create unique biopolymers like PBAT.

Polybutylene adipate terephthalate (PBAT)

Instead of heading to the landfill, PBAT can at the end of life bring food and other organics to industrial composters to create compost used to grow plants.

Figure 2. Polybutylene adipate terephthalate as an example of a fossil-based biopolymer which is compostable.
Biodegradable plastics are those that completely degrade through biological action into biomass, carbon dioxide (CO2), and water in a defined environment and in a defined timescale. These environments include industrial and home composting, anaerobic digestion, and marine and soil biodegradation. The FTC and various local authorities have specific requirements regarding biodegradation claims.

Figure 2 illustrates how biodegradable biopolymers like PBAT can be made from a fossil sources. These biopolymers can be used to make industrial compostable products like films or rigid packaging. Instead of heading to the landfill, at the end of use can bring food and other organics to industrial composters to create compost used to grow plants.

Other biodegradable bioplastic applications include soil and marine biodegradability. Soil biodegradability is useful for agricultural and landscaping applications including mulch films, which can be tilled into the field after use instead of being removed and landfilled. Marine biodegradability is useful in products that are designed for use in salt or freshwater environments. However, no form of biodegradation should be considered as a solution littering.

Biodegradability of plastics through industrial composting or other means provides alternative means for disposal of products. However, some compostable plastics such as PLA can be formulated for more durable applications and have the potential for being recycled as long as they are separated from other traditional polymers such as PET, HDPE, PP, etc. It’s anticipated that when greater volumes of PLA are available in the marketplace, it may become more cost-effective and there may be more interest in recycling this material.

The use of “degradable additives” such as oxodegradable additives are sometimes used to cause traditional plastics to fragment into smaller pieces. The resulting fragments are claimed to eventually undergo biodegradation. Degradable additives have not been shown in peer reviewed academic literature to convert nonbiodegradable polymers. For some plastics, recycling, composting and waste management experts have expressed concern that these treated products do not meet their environmental promises because the resulting fragments are not comprised entirely of materials known in nature.
This bag is certified compostable. It can be used to carry produce home from the store, and then reused to line a compost pail.

Compostable bags hold organic material, like food or yard waste, keeping the compost pail clean and helping transfer it to the industrial composter.

At the composting facility, the bag and contents are introduced in the process together. This may include shredding and mixing prior to entering the pile. In this controlled environment, conditions like heat, water, and time break everything down.

Microbes, such as bacteria and fungi, then consume these small pieces. Inside the cell, enzymes work to further break down the bioplastic for energy and raw materials. Simple molecules such as CO₂ and H₂O are excreted, and some of the carbon is incorporated into the cell's structure (biomass).

Within 3 months the composting process is typically complete and the resulting compost can be used to fertilize crops and flower beds.

Those plants could eventually be used to produce another compostable bag.
Compostable plastics are a subset of biodegradable plastics and are not synonymous with “biodegradable plastics.” Industrial compostable bags and food service items have helped make food waste collection programs around the world successful by increasing the amount of food waste diverted from the landfill waste stream. Many residential food scrap programs rely on compostable bags to facilitate participation. Special events, conference centers, and sports arenas increasingly use compostable food service items to simplify food scrap collection and work toward zero-waste goals.

“BIODEGRADABLE” VERSUS “COMPOSTABLE”
# List of Biopolymers

This list of biopolymers includes those that are commercially available or nearly commercially available. Not all grades of a polymer may meet the biodegradability noted; check with the material supplier for more information.

<table>
<thead>
<tr>
<th>Polymer Abbreviation</th>
<th>Polymer Name</th>
<th>Biobased?</th>
<th>Biodegradable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP</td>
<td>Cellulose Acetate Propionate</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>Cellulose Acetate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PA 10</td>
<td>Polyamide 10</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PA 1010</td>
<td>Polyamide 1010</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PA 11</td>
<td>Polyamide 11</td>
<td>Partially</td>
<td>Yes</td>
</tr>
<tr>
<td>PA 410</td>
<td>Polyamide 410</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PA 610</td>
<td>Polyamide 610</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PBAS</td>
<td>Polybutylene Adipate-co-Succinate</td>
<td>In Development</td>
<td>Yes</td>
</tr>
<tr>
<td>PBAT (ADIPIC ACID)</td>
<td>Polybutylene Adipate-Co-Terephthalate</td>
<td>Partially</td>
<td>YES</td>
</tr>
<tr>
<td>PBAT (azeliac acid)</td>
<td>Polybutylene Azaeli-Co-Terephthalate</td>
<td>Partially</td>
<td>YES</td>
</tr>
<tr>
<td>PBS</td>
<td>PolyButylene Succinate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PE</td>
<td>Polyethylene</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>PEET</td>
<td>Polyetherester Terephthalate</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PEF</td>
<td>Polyethylene Furanoate</td>
<td>In Development</td>
<td></td>
</tr>
<tr>
<td>PET</td>
<td>Polyethylene Terephthalate</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PHA</td>
<td>Polyhydroxy Alkanoate</td>
<td>Yes</td>
<td>YES</td>
</tr>
<tr>
<td>PLA</td>
<td>Polylactic Acid</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>PP</td>
<td>Polypropylene</td>
<td>In Development</td>
<td></td>
</tr>
<tr>
<td>PPA</td>
<td>Polyphthalamide</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>PTT</td>
<td>Polytrimethylene Terephthalate</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>TPC-ET</td>
<td>Thermoplastic Copolymer Elastomer</td>
<td>Partially</td>
<td></td>
</tr>
<tr>
<td>TPS</td>
<td>Thermoplastic Starch</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>TPU</td>
<td>Thermoplastic Polyurethane</td>
<td>Partially</td>
<td></td>
</tr>
</tbody>
</table>
Many residential food scrap programs rely on compostable bags to facilitate participation. Special events, conference centers, and sports arenas increasingly use compostable food service items to simplify food scrap collection and work toward zero-waste goals.
OVERLAP BETWEEN BIODEGRADABLE AND BIOBASED BIOPLASTICS

While biodegradability and biobased content are two distinct features of bioplastics, they are not mutually exclusive. In other words, some bioplastics have just one of these attributes, like a biobased water bottle that can be mechanically recycled with conventional PET, while other bioplastics may be both biobased and biodegradable. These bioplastics allow an end user to enhance the value proposition. For instance, if a biobased AND compostable bioplastic is used to make compostable food waste collection bags, then the product may offer both beginning-of-life (BOL) and end-of-life (EOL) environmental benefits, as seen in Figure 3 illustrates how some biopolymers are both biobased and in some way biodegradable, with contributions from the sequestration of carbon from photosynthesis as well as offering several options for renewal at end of life, including mechanically or chemically recycled, or by recovering captured energy.

To complicate matters, a bioplastic that is biobased and compostable in the raw form may lose compostability or biodegradability in a finished product. This can occur when a biobased and compostable bioplastic resin is used for a durable application, compounded with other materials to reach the desired specifications, and therefore loses the ability to be compostable. If a product is a bioplastic out the outset but not compostable or biodegradable as a finished product, standard principles of advertising substantiation, which require reliance on competent and reliable scientific evidence of the claimed environmental performance, will preclude promoting the product as degradable/compostable in its finished form.
Conclusion

Bioplastics can be both biobased and biodegradable. However, it is also possible for bioplastics to be only biobased or only biodegradable. The two properties are independent but can often be achieved in the same bioplastic. As such, bioplastics have a broad range of properties and characteristics and thus ways in which they can be used.
Endnotes

1 A summary of the Green Guides by FTC staff was issued in September 2012 and is found at https://www.ftc.gov/sites/default/files/attachments/press-releases/ftc-issues-revised-green-guides/greenguide_summary.pdf

2 For more information on the USDA BioPreferred Program and about getting a biobased product certified, go to https://www.biopreferred.gov/BioPreferred/


4 Issued February 2012


6 As with traditional petroleum-based plastics, bioplastics from biobased polymers without fillers are the easiest and most likely to be recycled, while the bioplastics produced from polymer blends or through biobased fillers in traditional polymers may be difficult to recycled or may contaminate the recycling stream.

7 For more information on the PLASTICS Bioplastics Division’s position on degradable additives, see the paper “Position Paper on Degradable Additives”