The Basics of Bioplastics: From Bio-based to Compostable

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Back to the future

Until the beginning of the 20th century, natural rubber and celluloid were the polymers that came closest to the plastics that we know today. Slightly altered natural polymers were used to make things like tires and hair combs. That was until 1917, when Leo Baekeland came up with the first fully fossil-based plastic: Bakelite. The rest is history. For more than a century, fossil-based plastics have dominated our economy, but that may be changing. Due to public pressure and increasing legislation and policies that pursue a circular economy, nature-based materials are back in the spotlight. What are today's bioplastics? This article aims to explain the concept and forms of bioplastics in order to clear up some common misconceptions.

Bioplastics, Bio-based and Biodegradable Plastics: What Is What?

Bioplastics are a group of plastics that are either bio-based, biodegradable or both. It can be confusing that some types of bio-based plastics are non-biodegradable while some fossil-based plastics can, in fact, be biodegradable. Table 1 shows the categorization of the different types of bioplastic:

Table 1: Classification of bioplastics

	Bio-based	*Partly bio-based*	*Fossil-based*
Biodegradable	TPS, Starch blends (with bio-based and biodegradable copolymers) PLA, PHA/PHB Cellulose acetate	Starch and PLA blends Both if blended with biodegradable fossil-based copolymers	PBS, PBSA PCL, PBAT
*Non-biodegradable**	Bio-PE, Bio-PP Bio-PET, Bio-PTT Bio-PUR, Bio-PA (6, 66)	Starch blends (blended with PE/PP) PTT, PET (blend) PEF (blend)	PE, PP, PVC PET, PBT, PUR PA6/PA66, ABS **

* Note 1: Conventional plastics like PP, PE and PET can be fully bio-based, fossil-based or blended.
** Note 2: Non-biodegradable, fossil-based plastics are not bioplastics.
Source: Shen, L. (2009) Product overview and market projection of emerging bio-based plastics

Bio-based plastics

Bio-based plastics are made from up to **100% non-fossil renewable feedstock**. Most feedstock comes from sugars from sugar beets or sugarcane, or from starches from corn, potatoes, or wheat. A smaller portion of bio-based plastics is derived from vegetable oils like castor bean seeds or cellulose from wood. Bio-based plastics can be chemically similar to their fossil-based counterparts. Some are biodegradable; others are not. Bio-based plastics should not be confused with biopolymers, which are natural polymers created by nature, such as wool, starch, and sugar.

Biodegradable versus compostable

Biodegradable plastics can be broken down by bacteria or fungi into water, carbon dioxide (CO_2), methane (CH_4), and biomass. The degradation rate of a biodegradable plastic differs depending on humidity, soil quality, oxygen levels, and temperature. Biodegradable plastics can be used in compostable plastic products. **Compostable** plastic products biodegrade in a specific timeframe, generally only under industrial composting conditions. In Europe, a material can only be categorized as compostable if it is in compliance with the European Standard for compostable materials (EN13432). The European Standard specifies a maximum of 12 weeks for the bioplastic to degrade.

In theory, all bio- and fossil-based biodegradable plastics can be industrially composted, but compostability also depends on the design of a specific product or type of packaging. The more solid the product or the thicker the wall of a piece of packaging, the less likely a product will be compostable within the 12 weeks.

Some biodegradable plastic products are home compostable. Currently only PHA/PHB and TPS can degrade under the lower temperatures (28 degrees Celsius) of home composting compared to the higher industrial composting temperatures (50-70 degrees Celsius).

Drop-ins and chemically novel products

Non-biodegradable bio-based plastics are considered **drop-ins**. Because they are chemically identical to their fossil peers, it is possible to blend them or use them to fully replace a fossil counterpart. One example is Bio-PET30, which is a fossil-based PET with 30% bio-based content. Due to the 20% to 100% price premium typically charged for drop-in feedstock, many off-takers of plastic (packaging) products are still hesitant to replace fossil-based plastics with bio-based drop-ins at a large scale. In addition, supply is still limited.

Most biodegradable bio-based plastics are considered **chemically novel**. That means they are a new product class, with new material properties. For example, PLA has high stiffness and PHA is biocompatible with tissues and organs, making it useful for medical applications. Prices of chemically novel bioplastics range between USD 2,000 to 7,000 compared to a range of USD 900 to 1,300 per metric ton of resin for polyolefins (HDPE, LDPE, PP).

Hurdles and opportunities

Being compostable and/or made from a renewable resource are two clearly positive features of bioplastics. Still, there remain hurdles for larger-scale market uptake, beyond the costs and properties of the materials.

Bioplastics cause confusion among consumers, who cannot distinguish one plastic from another. In addition, current waste management systems are not set up to sort biodegradable plastics. This results in bad waste management where non-biodegradable plastics end up in compost or compostable plastics end up in waste-to-energy plants. Bioplastics can also contaminate the current plastic recycling processes. PET and PLA, for instance, are not distinguishable in the current sorting processes, but have different melting points. This can cause problems in the production processes of recycled PET products and packaging. Clear labeling and public education about this new group of plastics are necessary in order for them to have a place in a future circular economy.

Regulatory support could stimulate demand, but specific policies to increase the use of bioplastics are currently rather scarce. . The best example is China's ban of non-biodegradable single-use plastics (SUPs), which encourages the use of compostable SUPs. China has also granted tax compensations in specific regions to boost production of biodegradable plastics. Japan has introduced a plastic bag fee, with an exemption for bags composed of +25% bioplastics. Europe and the United Kingdom are focused on standardizing and assessing the benefits of bioplastics.

Italy is one of the only European countries with a clear policy to stimulate production of biodegradable bio-based plastics. The country has increased industrial composting capacity while introducing compostable bags and educating consumers on the proper disposal of biodegradable bioplastics. This strategy is proving successful. Consumers can distinguish bio-based plastics and, in turn, industrial composters are able to produce high-quality compost

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