HOW GREEN ARE GREEN PLASTICS?

Composting managers have to know the differences among the various plastics that are marketed as degradable, biodegradable, and compostable, so that they can maintain customer confidence in their end products.

E.S. Stevens

THE SAGA of how plastics and compost are getting along continues to unfold. Will plastics and compost continue to be at odds, or are the efforts at making plastics compatible with composting beginning to pay off? "Green" plastics get their name from the "green chemistry" movement, which seeks to lessen the chemistry industry's impact on the environment. As far as plastics in compost is concerned, the most relevant "principle" of green chemistry is that products, at the end of their function, should break down into innocuous degradation products.

Two of the evolving green plastics issues are described in this update. The first is that composting managers have to know the differences among the various plastics that are marketed as *degradable*, *biodegradable*, and *compostable*, so that they can maintain customer confidence. Yet, the terminology in this area can be confusing.

Second, the composting and "green plastics" industries have mutual interests. Composting facilities and feedstock producers want to keep their products free of nondegradable plastics that increase costs and lower quality. The plastics manufacturers aim to develop large-scale markets for compostable plastics.

TERMINOLOGY AND STANDARDS

There are two reasons the terminology can be confusing: 1) The terminology has to be technically precise enough to avoid ambiguity; and 2) Definitions have to be operational, i.e., based on specific scientific measurements, so that the plastic can be assigned to a category on the basis of science and not on the basis of manufacturers' claims. Standardization brings order to the industry.

Standardization has come a long way since the early 1990s. In the United States, the major role player in that regard is the American Society for Testing and Materials (ASTM), which has developed definitions relevant to the degradation of plastics. At the risk of oversimplifying those technical definitions, an attempt is made here to capture the important distinctions: *Degradable plastic* — A plastic designed to undergo degradation under specified conditions as measured by standard test methods; *Biodegradable plastic* — A degradable plastic in which the degradation results from the action of naturally occurring microorganisms such as bacteria, fungi, and algae; and *Compostable plastic* — A plastic that undergoes degradation by biological processes during composting to yield carbon dioxide, water, inorganic compounds, and biomass at *a rate consistent with other known compostable materials* (emphasis added) and leaves no visually distinguishable or toxic residues.

A plastic can be *degradable* without being *biodegradable*; i.e., it might disintegrate into pieces or even an invisible powder, but not be assimilated by microorganisms. A plastic can be *degradable* and even *biodegradable* without being *compostable*; i.e., it might biodegrade at a rate that is too slow to be called compostable.

The most difficult (and controversial) part of developing standards has been to spell out what is meant by "*a rate consistent with known compostable materials*." What known compostable materials should serve as references?

In Europe, environmental legislation is ahead of the United States. Germany, for example, pioneered legislation for discarded packaging when it made industry and trade responsible for used packaging through the "Green Dot" system. Packagers are now obliged to collect their own waste for recycling, or to contract with the company formed to oversee the system (Duales System Deutschland) for collection and recycling. A small green dot labels products of contracting producers. Packaging producers, seeing themselves as the liable parties in matters of used packaging, pressed for strictness in standards. In response, European standardization organizations moved toward defining the rate required for bearing the label "compostable" in terms of "known compostable materials" that are more or less readily compostable, such as paper (cellulose). Cellulose is more readily compostable than, say, wood; in addition to cellulose, wood contains 15 to 25 percent lignin, which also biodegrades but at a slower rate than cellulose.

The final result was a requirement that plastic packaging be subjected to scientific tests to show that, after 180 days in a composting environment, it had converted to carbon dioxide to the extent of no less than 60 percent or 90 percent, with the percentage depending on the nature of the polymers in the material. Additional tests were required after 180 days to show that no more than ten percent of the original weight is left on a 2-millimeter screen, and also that heavy metals content is within specified limits.

In the United States, the ASTM developed its own specification for establishing criteria to be met before a product can be labeled compostable, and similarly adopted readily compostable materials as a reference point, mentioning cellulose explicitly. The ASTM standard (ASTM D-6400 entitled "Standard Specification for Compostable Plastics") therefore resembles German (DIN-54900), European (EN-13432), and international (ISO-14855) standards.

Products that comply with the ASTM standard, as confirmed by independent testing, can bear a logo developed jointly by the international Biodegradable Products Institute (BPI) — a government- industry-academic association that promotes the use of biodegradable polymer materials — and the U.S. Composting Council (USCC) — representing the composting industry. Products that have been certified as compostable are identified on the BPI website at www.bpiworld.org.

Discussion continues within the standardization community as to whether less rapid biodegradation (than required by ASTM D-6400) is acceptable for compostability; i.e., whether less rapid carbon dioxide evolution may still be suitable for purposes of providing long-term soil enhancers. (Wood and leaves, for example, do not meet the ASTM standard.) It is possible that ASTM will develop a second standard of compostability aimed at plastics that degrade more slowly, but the outcome of the ongoing discussions may not be known for some time. Great care is being taken because the potential impact of accumulated undegraded plastic residues (e.g., polyethylene) on long-term agricultural productivity is an important issue.

PRODUCT DESCRIPTIONS

The BPI/USCC logo is designed to assure composting managers that certified products will biodegrade completely and safely within the required time; in turn, those managers can assure their clients. Examples of some of the marketed products are noted here together with their environmental attributes vis-à-vis ASTM D-6400.

MaterBi™, manufactured by Novamont S.P.A. (Italy) (www.materbi.com), contains starch blended with petroleum-based, but biodegradable, polymers (e.g., polycaprolactone); the latter provides water resistance and added strength. Biodegradable bags and films of two manufacturers that use MaterBi have been certified with the BPI/USCC logo: Biocorp North America (www.biocorpna.com) and Polargruppen A/S (www.biogroupusa.com).

Eastar Bio™ copolyester, manufactured by Eastman Chemical Company (www.eastman.com), is a random poly(butylene adipate-*co*-terephthalate) polyester containing 50 percent terephthalate. Eastar Bio copolyester biodegrades to the extent of 80 percent in 150 days in a composting environment. Biodegradable bags and films made with Eastar Bio copolyester have been certified to bear the BPI/USCC compostable logo.

Ecoflex® and Biomax® are copolyesters manufactured by BASF (www.basf.com) and DuPont (www.dupont.com), respectively. They are biodegradable but have not yet been through the BPI/USCC certification process for compostability.

NatureWorks™, manufactured by Cargill Dow Company (www.cargilldow.com), is based on poly(lactic acid) (PLA). PLA is a polymer synthesized from lactic

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acid, produced from fermentation of a sugar often obtained from the conversion of a starch feedstock such as cornstarch or potato peels. After disposal, PLA degrades mainly by hydrolysis, even in the absence of enzymes. So whereas PLA is compostable, the role of microorganisms in its degradation is variable and limited. The main applications of PLA to date have been in fiber products and clear packaging containers, but Biocorp North America has announced plans for combining NatureWorks PLA and MaterBi in blends to be used for compost bags.

"Activated polyolefins" are polyolefins (usually polyethylene or polypropylene) in which the environmental degradation is enhanced. (Polyolefins themselves degrade by oxidation, but the rate in the environment is extremely slow; they are environmentally *recalcitrant*.) In activated polyolefins, additives are incorporated (about three percent by weight) into the polymer during processing to induce accelerated oxidative degradation initiated by natural daylight, heat, and/or mechanical stress. Additives are manufactured by companies such as EPI (Environmental Plastics, Inc.; www.epi-global.com). The additives are then sold to companies that process it together with polyethylene to produce plastic film for bags and other products. Activated polyolefins are degradable but are not, by current standards, compostable; they will have market acceptance where the ASTM D-6400 specification is not mandated.

In starch-filled polyethylene bags, the polyethylene encapsulates the starch granules and biodegradation of the starch component leads to fragmentation; additives aim to enhance degradation of the polyethylene. A starch-polyethylene "masterbatch" is manufactured by companies such as Willow Ridge Plastics, Inc. (www.willowridge-plastics.com). The masterbatch is then sold to companies that process it together with

POLY WHAT?

THE expression, "It's Greek to me," is quite apropos when discussing plastics that are manufactured to degrade or biodegrade in a composting environment. Dr. Eugene Stevens, author of *Green Plastics: An Introduction to the New Science of Biodegradable Plastics* and the accompanying article, does an excellent job of explaining the chemistry behind these families of plastics. The purpose of this sidebar is to put some definitions to the words we see associated with green plastics.

Recalcitrant – Resistant to degradation.

Polymer – Substance consisting of molecules characterized by the repetition of one or more types of monomeric unit (monomer, meaning single or sole).

Polymerization: Chemical reaction in which low molecular weight monomer molecules react to form polymers. Polymers can be distinguished by their chemical formulas.

Homopolymer: A polymer resulting from polymerization of a single type of monomer.

Copolymer: Polymer formed from more than one type of monomer.

Polymer Additives: Most polymers are of little practical value by themselves because of poor physical properties. Therefore, almost all plastics contain chemical additives, either to facilitate the handling or fabrication process or to produce some particular desirable property in the final product (e.g. degradation).

Plastic Categories (in terms of degradation): Nondegradable: Maximum resistance to all types of degradation. Characteristics: Generally strong, water resistant, and microorganisms do not readily attack. Includes polyolefins such as polyethylene, polypropylene; Readily degradable: Destructs after its useful life; is assimilated by the pervasive organisms found throughout nature. Typically specialty polymers used in detergents, water treatment. Can be made from fossil resources; Programmed degradable plastics (controlled degradation): Program plastics to degrade in a predetermined time under specific conditions according to the needs of particular applications.

Degradation: A deleterious change in the plastic's appearance, physical properties or chemical structure. Describing, measuring and controlling degradation is complicated by three factors: 1) Plastics can, and do, degrade by many routes (physically, chemically and biologically), consecutively and simultaneously; 2) How plastics degradation proceeds in a specific case depends on the environment in which the plastics are placed (e.g. dry air, light, soil, hot and/or moist conditions, etc.); 3) Regardless of the environment, the rate of plastics degradation also depends on the chemical composition of the plastic.

Dr. Steven's book, *Green Plastics*, does a superb job of discussing degradability/biodegradability factors related to a particular plastic's chemical composition. That chemical make-up leads some plastics to degrade more rapidly than others because their constituent polymers are chemically different. Notes Stevens: "The rate of biodegradation, in particular, depends on the polymer's characteristics because the polymer is the substrate for the enzyme (protein molecules that catalyze biochemical reactions)." A future article will discuss the chemical make-up of the various plastics that are marketed to the composting industry. — N.G.

polyethylene to produce plastic film for bags and other products. Starch-filled polyethylene bags also do not meet the ASTM D-6400 standard for compostability.

MUTUAL INTERESTS

The composting and green plastics industries have long-term mutual interests, as well as interests of immediate concern. In the future, compostable waste other than yard trimmings may become a very large feedstock for composting facilities. Many states, interested in increasing their overall recycling rates, have already begun improving infrastructures for the collection and composting of diverse organic feedstocks from industrial, commercial, and institutional sources, including food residues and nonrecyclable paper and cardboard. Although residential curbside collection of organic compostables is almost nonexistent in the United States, except for yard trimmings, even that source of feedstock may one day become significant.

In the future, diversification of feedstocks could be extended to include all sorts of compostable plastic items, including packaging film; bottles and jars; loose-fill and rigid foam packaging; food-service items including cutlery, plates, cups, and trays; and consumer products, such as diapers, personal care and hygiene articles, sports and recreation items, and others. The green plastics manufacturers see that they have a vested interest in a growing composting industry, for if compostable plastics are not going to be composted, why do they have to be compostable?

At the present time, however, the mutual interest lies mainly in collection bags for compostable materials. With collection bags, compostability serves an intrinsic function that gives the product a performance capability that often cannot be matched by alternative products. Nondegradable bags add to composting costs (they have to be separated from the waste to avoid contamination and they require disposal) and can degrade quality (if separation is imperfect). Compostable waste bags avoid those problems.

Composting managers now have a choice as to which compost bags to purchase. Their decisions will be based largely on cost/performance ratio, where performance will include environmental attributes as well as physical properties. Environmental attributes are easier to determine now that industry standardization has led to ASTM D-6400.

With respect to physical properties, two of the most important are strength and shelf life. For information, purchasers have to rely on a combination of manufacturer's claims, personal experience, and published reports such as those in *BioCycle*. Generally speaking, manufacturers aim to match the strength of low-density polyethylene film.

Cost is a crucial factor. None of the green plastic compost bags will match the low cost of polyethylene, but once the costs of emptying and disposing of nondegradable polyethylene bags are taken into account, those trade-offs bring the real costs within range of one another. Bulk purchasing also makes a difference in cost, which is what makes the shelf life of the bags relevant as well as the size of the collection operation.

Manufacturers of green plastics compost bags are vying for their market share, and the total market will grow as the composting industry grows. Composters want to deliver a clean product at a reasonable cost. The industries appreciate this interdependency and have begun to join forces through cooperative efforts, such as the joint certification initiative between BPI and the USCC. Moreover, now that standardization has been achieved and a compostable logo made available, it will be easier for local and state legislatures and executive branches to formulate restrictive dictums, making it possible that regulatory actions will play roles in purchasing decisions. In the end, it is clear that the composting industry and the green plastics industry will continue to have overlapping interests. ■

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