WHITE PAPER

Composting biodegradable plastics: A technical review

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Abstract

Biodegradable plastics have the potential to reduce the environmental impact of plastic pollution, while certified compostable plastics have the long-term potential to divert substantial amounts of waste packaging materials from landfills. Despite the growing role of compostable products, many regulators and users cite concerns about unpredictable or incomplete breakdown of biodegradable plastic.

Composting is the accelerated degradation of heterogenous organic matter by a mixed microbial population in a moist aerobic environment under controlled conditions. Currently many commercial composting facilities only address garden and food waste and are not adapted to processing biodegradable plastic. Although collection of biodegradable plastic into municipal organic waste streams is increasing in some regions, evidence to show they are contributing to overall compost quality is scarce and sometimes contradictory.

Biodegradable plastic breakdown occurs through a synergy of abiotic and biological processes. The ultimate result is a reduction in the molecular weight of polymers followed by biological conversion of the polymer breakdown products into carbon dioxide and water. Microorganisms use various mechanisms to degrade complex polymeric material including direct use of plastic fragments as a nutritional source or via the indirect action of microbial enzymes. The presence and abundance of microbial species is highest in compost, followed by soil, fresh water, marine water and finally landfills.

The goal of this technical review is to provide insight into biodegradable plastic degradation, compost processes and the role biodegradable plastics can play in reducing plastic pollution and generating valuable compost.

Keywords: biodegradable plastic, compostable foodservice products and packaging, plastic biodegradation, compost, soil health

Introduction

Slow and varying biodegradation rates between different compostable products and lack of information on environmental impacts are key problems facing the biodegradable plastic industry. This technical review provides a detailed examination into the compost process, the biodegradation behaviour of common biodegradable plastics and the impact of these materials on compost quality and soil health. Case studies on the use and acceptance of compostable products are also assessed to understand the current waste management systems for these materials.

Biodegradable plastics (BP) have the potential to reduce the environmental impact of plastic pollution, while certified compostable plastics (CP) have the long-term potential to divert substantial amounts of waste packaging materials from landfills, providing a useful soil amendment for agricultural production.[1]

Biodegradable plastics have been gradually introduced into the global market, with Asia being the major production hub for these new materials, producing 55% of the worlds biodegradable plastics in 2018.[2] A surge of public interest is driving regulating bodies and the plastic industry to establish infrastructure and standards to govern recycling and end-of-life (EoL) processes for biodegradable materials.[3,4,5] Recent case studies[6,7,8] have emphasized that to ensure the theorised environmental safety and applicability of BP, proper waste management and community training plans must be developed in parallel.[9,10]

Biodegradable plastics can be made from materials such as starch, cellulose or polyesters and many are marketed to quickly disintegrate in commercial compost environments. Although several certification protocols are available to determine the compostability of biodegradable plastics,[11] these protocols are mostly based on simulated composting conditions; biodegradation under real-world compost operations is often unsatisfactory, leaving microplastics to be screened out of the final compost. This discrepancy between policy and practice is exacerbated by waste stream contamination resulting from confusion among food service establishments and consumers as to what type of packaging is recyclable and/or compostable, with the unfortunate result that many municipal composters will not accept biodegradable plastics.[6]

Compost as a soil amendment

Compost has many roles as an agricultural supplement, not just to enrich soil with essential elements for growth and development, but also to contribute to the improvement of soil structure and to impart a more stable soil equilibrium.[12] Compost enriched soil can reduce erosion, alleviate soil compaction and help control disease and pest infestation in plants.[13] Nutrient content in compost can be low due to several factors, including age of the compost, amount of water added, plant species, and the amount of soil that becomes mixed into the pile during turning.[14] It can be necessary to supplement compost with some fertilizer, particularly nitrogen. If the carbon-to-nitrogen ration ratio (C:N) of the compost is less than 20 to 1, nitrogen will tend to be released rather than tied up. Compost that is immature or not well decomposed may result in nitrogen deficiency and poor plant growth. The pH of mature compost should be between 6.0 and 8.5 to support plant growth.[15] Slightly alkaline pH however, are beneficial to plants growing on acidic soils. Electrical conductivity reflects the salinity of the compost. Salt concentrations increase during composting due to the decomposition of complex organic matter. If these concentrations get too high, the osmotic pressure between plant roots and the growth substrate decreases impacting water uptake.[16] To support the growth of plants, the electrical conductivity of mature compost must be lower than 2.5 mm hos cm^{-1}. Particle size distribution of the final compost is also important as it determines the maintenance of adequate porosity for gas and water exchange through the soil.

The compost process

Composting involves sequential growth and depletion of microbial subpopulations, the presence of which can positively or negatively impact the compost process.[17]

Composting generally occurs in four stages: mesophilic, thermophilic, cooling and maturation (Figure 1). In the beginning of the compost process, mesophiles are the dominant species present. These microorganisms grow between 15 and 35 °C and are responsible for initial breakdown of organic material by utilizing readily assimilable compounds such as sugars, amino acids and lipids. Metabolic activity and growth of these mesophilic species leads to heat evolution and a rapid increase in temperature to 65-75 °C. This rise in temperature causes mesophilic populations to be succeeded by thermophiles including actinobacteria and Bacillales, which can decompose complex molecules like cellulose and lignin.[12,15] Importantly, the elevated temperatures in this stage also kills weed seeds and soil borne pathogens. As energy sources are depleted, metabolic activity decreases, and the compost cools down to temperatures between 15 and 35 °C, leading to a second colonization of mesophiles which break down any remaining sugars. Finally, in the maturation stage, the compost is stabilized as precursors to humic substances are formed.

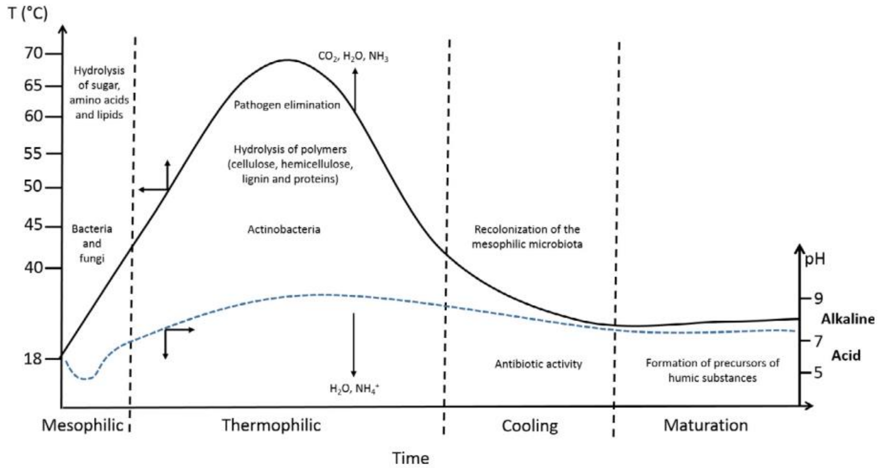

Figure 1. Time profile of the average pile temperature during the compost process. Solid black line is temperature. Dashed blue line is pH.[12]

Factors which influence the compost process

The main factors controlling the compost process are C:N ratio, temperature, pH, moisture content and aeration.[18,19]

During composting microorganisms' breakdown organic matter to obtain energy and acquire nutrients to sustain their populations. Essential elements are carbon (C), nitrogen (N), phosphorus (P) and potassium (K), however C and N are the most crucial. Carbon is used as an energy source and microbial species mineralize C to release CO_2. The release of 50 – 150 milligrams of CO_2 per gram of volatile solids (mg CO_2 / g VS) over the first 10 days indicates active composting.[18,19] Nitrogen is used for building cell structures and is taken up by microbes and mineralized to ammonia and subsequently to nitrites (NO_2^-) and nitrates (NO_3^-). As such, N mineralization and NO_3^--N/NH_4^+-N ratios are good indicators of compost maturity. When the amount of N is limited, microbial growth decreases, however if excess N exists, then this is volatized as ammonia gas, increasing the C:N ratio. Adjustment of raw materials to give a C:N ratio of 25-30:1 is ideal for active composting.[15]

A significant temperature gradient occurs temporally in compost and temperature is a significant factor in determining relative advantage of some microbial populations over others. The inhibition of thermophiles at low pH leads to a lag in the transition from mesophilic to thermophilic conditions. Elevated temperatures and excess ammonia generation can inhibit the growth and activity of nitrifying bacteria in the thermophilic phase, impacting nitrogen mineralization. Compost temperatures that exceed 60-65 °C can kill almost all microorganisms causing composting to cease.[12]

Important because of its influence on microbial populations, pH generally follows a pattern during composting whereby a decline is observed in initial stages followed by an increase in pH during later stages. The initial breakdown of organic matter generates low molecular weight carboxylic acids which lower pH, as the composting process continues, pH rises as these compounds are further metabolized.[16,20] Alkaline conditions favour the formation of NH_3, rather than water soluble form NH_4^+ which can lead to loss of nitrogen through volatization as well as causing odour issues.[21] Very acidic conditions also pose a challenge during industrial composting, as the transition from mesophilic to thermophilic stages can be negatively affected.[16]

Composting is a mainly aerobic process where microorganisms use oxygen to oxidize carbon from organic materials producing CO_2, H_2O, humus and heat. If air flow is too low, oxygen becomes the limiting factor and metabolic action slows, conversely high oxygen flows can dry and cool the compost, slowing down microbial growth.[19] Another factor considered is moisture content which influences oxygen uptake rate, free air space, microbial activity and temperature. Increases in moisture content cause a decrease in gas diffusion and oxygen uptake becomes inadequate to meet the needs of microbial communities.[15] Active microorganisms incorporate nutrients from waste into biomass. Depletion of these nutrients could limit the composting process. As such, the objective of compost supplementation is to obtain an ideal balance of nitrogen, phosphorus and carbon to achieve the appropriate conditions to start fermentation and favour the growth and development of microbes.[17]

Commercially available biodegradable plastic resins[22]

Poly(lactic acid) or **PLA** is the dominant biodegradable plastic resin available in the North American market, though it only makes up 24% of the global market for biodegradable plastics. PLA is the most commonly used packaging or single-use item material and has been blended with other materials to improve its strength.

Poly(hydroxybutyrate) (**PHB**) and poly(hydroxy butyrate-co-valerate) (**PHBV**) belong to the family of bacterial polyesters, poly(hydroxyalkanoates)s or **PHA**s. Currently PHAs are 6% of the global market for biodegradable plastics, though this is expected to increase over the next 5 years. PHB is highly crystalline and brittle whereas PHBVs are copolymers that can be tailored to have different strength and elasticity.

With the emergence of bio-derived succinic acid, terephthalic acid, adipic acid and 1,4,-butanediol, poly (butylene succinate) (**PBS**) and poly(butylene adipate terephthalate) (**PBAT**), can now be bio-based and biodegradable. These plastics have melting temperatures similar to those of polyethylene and polypropylene. Combined, these two materials make up 27% of the global market for biodegradable plastics.

Thermoplastic starch (**TPS**) is completely bio-based and biodegradable but is fragile compared to petrochemical-based polymers. Because of their proven biodegradation ability, starch-polyester blends (**SPB**) are the leading biodegradable plastic products sold in the EU and they make up 42% of the global market (Figure 2a).

Many biodegradable plastics do not perform as well as their established nondegradable counterparts and are often blended together to combine characteristics and offer more functionality in their application (Figure 2b). Proprietary commercial blends are developed by resin producers for use in different applications and forming processes and are sold generally sold under specific brand names.

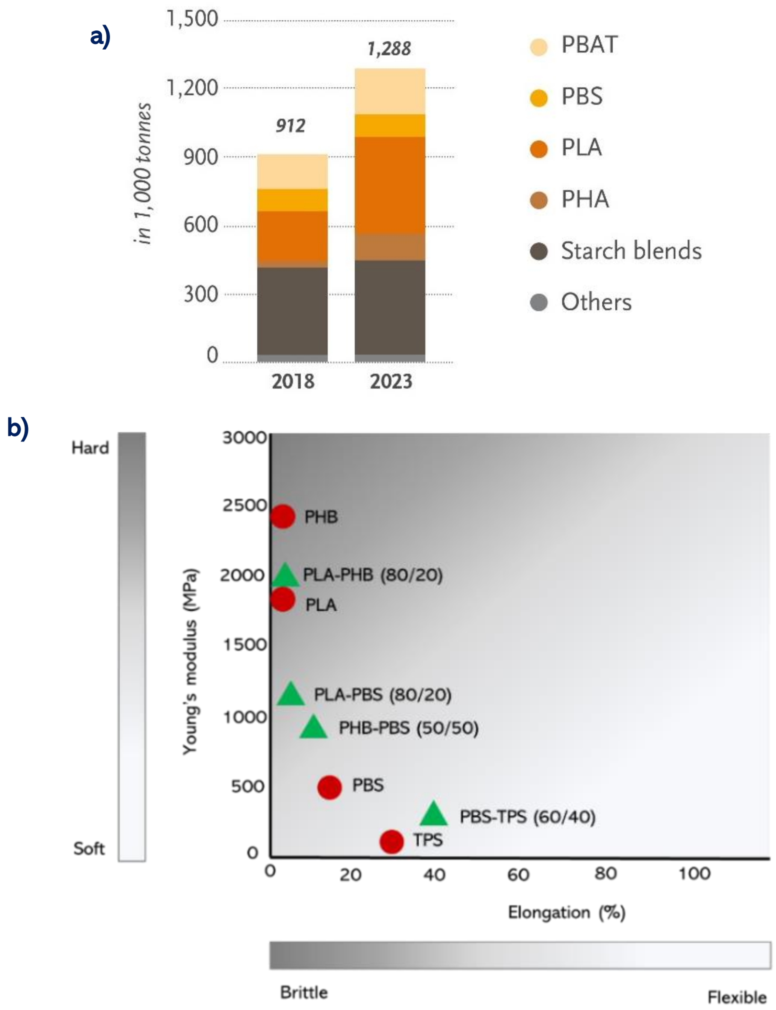

Figure 2. a) Biodegradable plastic production for 2018 and 2023.[2] **b)** Mechanical properties of biodegradable plastics (red circles) and their blends (green triangles). By blending these biodegradable polymers with each other they can be designed with tailored properties. [22]

Degradation of plastic

Any plastic breakdown occurs through a synergy of abiotic and biological processes. The ultimate result is a reduction in the molar mass of polymers followed by biological conversion of the polymer breakdown products into carbon dioxide and water.[23]

Biodegradation of plastic material occurs in three symbiotic stages: (bio)deterioration, bio-fragmentation and assimilation (Figure 3).[24]

- *(bio)Deterioration* is the process whereby microbial and/or abiotic factors break-up the material into tiny fragments. Abiotic degradation processes contribute to weakening of the polymeric structure. These processes include mechanical degradation, light degradation (*via* radical reactions), thermal degradation and chemical degradation (*via* hydrolysis and oxidation). Biodeterioration is the result of microorganisms growing on the surface/inside the material. Microbes secrete enzymes which penetrate the polymeric structure, opening channels which allow the influx of air and moisture.
- The process of *depolymerization* reduces the molecular weight of polymer chains allowing them to cross the cell membrane. This step occurs under the action of enzymes secreted by microbes. These enzymes act through hydrolytic, oxidative or radicular pathways and can either cause random chain or chain-end scission.
- *Bioassimilation* occurs when microorganisms are using the polymeric material as a primary nutrient on which to grow and reproduce.

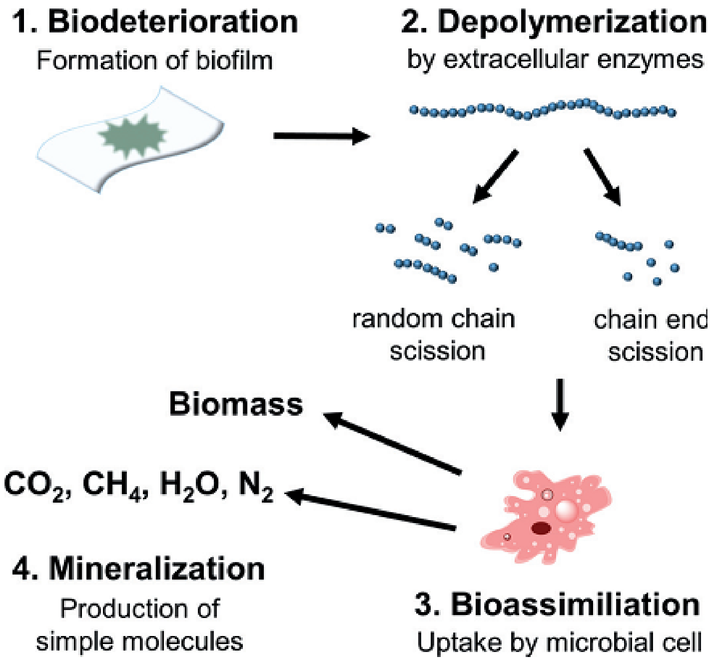

Figure 3. Schematic illustration of steps involved in plastic biodegradation.[25]

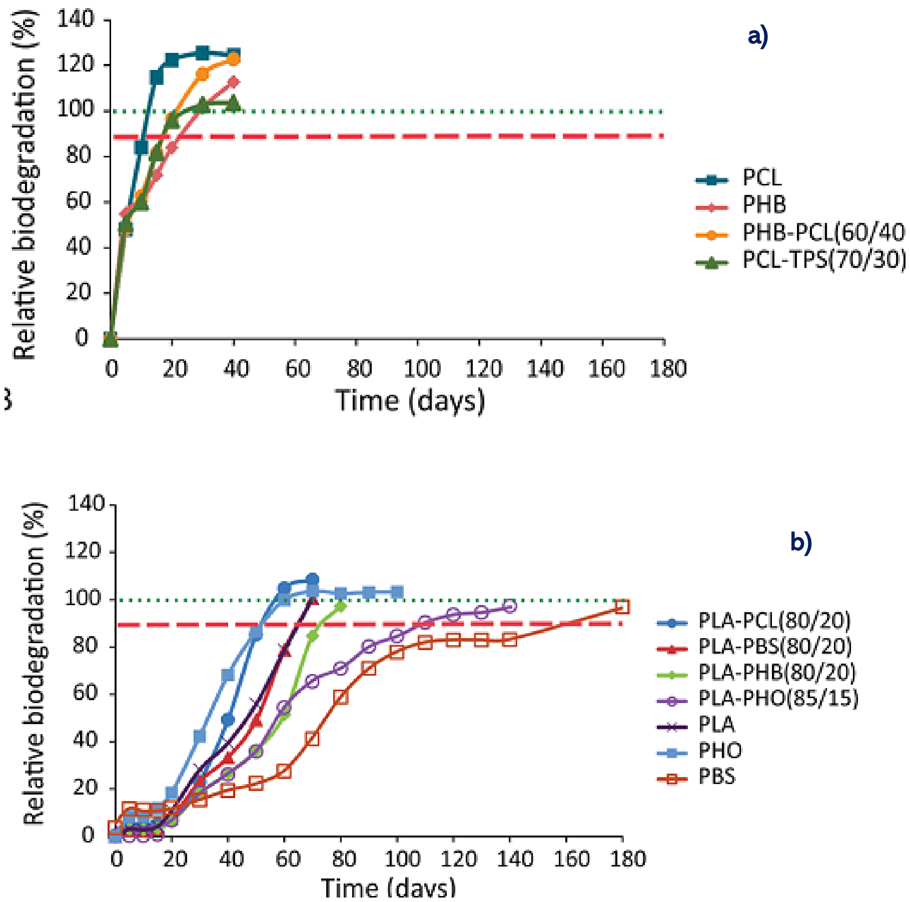

Figure 4. Relative biodegradation of biodegradable plastics in industrial composting. The green dotted line represents degradation level of cellulose, which is completely degraded during this test. The red dashed line represents the cut off value of 90% relative biodegradation for the biodegradation test. **a)** Fast degrading materials. **b)** Materials showing slow degradation. [26]

Biodegradable plastic degradation

Biodegradable plastics break-down in three phases: lag, biodegradation and plateau. The length of each stage depends on the polymer. Naturally occurring polymers such as cellulose and PHB display a very short lag time associated with the acclimatization of microbial species to the environment (Figure 4a). Conversely, polymers such as PLA, PBAT and PBS tend to show a longer lag period (Figure 4b).[26]

An interplay between abiotic and biotic hydrolysis exists during the initial stages of the degradation process, and recent literature suggests that abiotic hydrolysis in the main contributing factor in degradation of high molecular weight polymers.[24] Thus, the lag in the degradation process is ascribed to the initial diffusion of water into the polymer matrix before breakdown into oligomers and monomers.

The biodegradation phase can be further understood as occurring in two steps: primary external degradation where readily, moderately and slowly hydrolysable carbon is converted to water-soluble ‘intermediate carbon’ (monomers, oligomers and lactic acid); and ultimate internal degradation where this intermediate carbon is mineralized to CO_2, water and humic substances (Figure 5).[27] Enzymatic hydrolysis only begins when polymer molecular weights reach 10 kDa, though molecular weights as low as 2-3 kDa are required before oligomers are water soluble.[19] The generation of these low molecular weight compounds decreases the pH of the surrounding environment leading to autocatalytic degradation of biodegradable polyesters. The low pH in this stage of biodegradation can have negative impacts on microbial species during composting. Depending on the compost environment and method, PLA products have been shown to degrade after 60-100 days at 50 – 60 °C.[13]

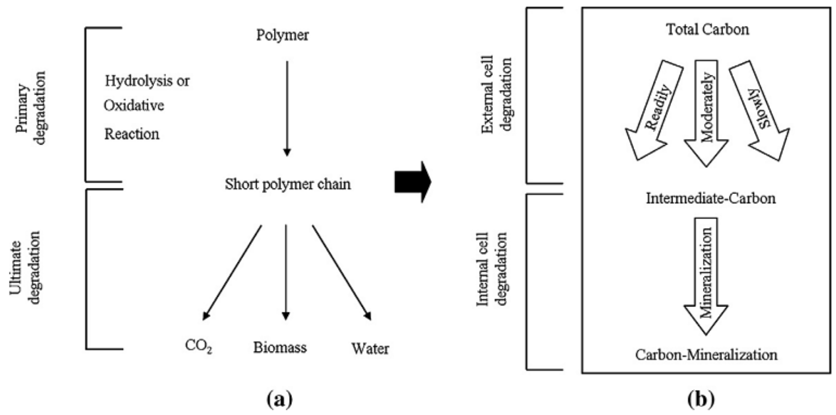

Figure 5. (a) Flowchart of biodegradation mechanism of biodegradable polymers and **(b)** proposed carbon degradation during aerobic composting.[27]

Microorganisms involved in biodegradation of BP

More than 90 types of microorganisms including aerobes, anaerobes and photosynthetic bacteria have been found to be active for the biodegradation and catabolism of biodegradable plastics.[27] They can form consortia called biofilms, microbial mats that work in synergy to breakdown polymeric material.[24] Development of microbial species in a specific order increases biodeterioration as some microorganisms may utilize intermediates of bioplastic degradation by the main organism. BP-degrading microbes are also abundant in nature, with both compost and soil containing high numbers of BP-degrading microorganisms.[23,28] One study found 16 out of 79 microbes isolated from soil samples were active degraders for PLA and PBS according to the clear zone method.[29] The precise chemical changes and complex metabolic processes of various microorganisms occurring during composting process vary with the composition of composting materials.[18] Some BP have been observed to enrich soil microbial communities with certain taxa, causing increases in microbial biomass and enzyme activities.[30] These changes suggest the potential for enhanced nutrient and carbon cycling under BP. One study exploring methods to improve BP composting showed that increasing the soluble sugar content through the addition of high protein additives improved polymer degradation.[31] These additives promoted the growth of polymer degrading microorganisms allowing the BP to be degraded more efficiently.

Actinobacteria form a class of BP catabolites that are distributed throughout the world in different climate zones, both on land and in water.[32] They can grow in mesophilic and thermophilic environments and possess the ability to degrade complex substrates.[12] Several species of the bacterial group have been found in compost and investigated for compost applications. Thermophilic actinomycetes isolated from Taiwanese soils were found to degrade three common biodegradable polyesters.[33] In addition, different actinomycete species have plant-growth promoting properties like phosphate solubilization and induction of root nodules.[27]

Filamentous fungi play an important role in the biodegradation of BP. In early stages of biodegradation, the growth of hyphae into the surface of the plastic aids in fragmentation. The hyphae are also able to transport enzymes into the bulk of the plastic allowing for internal degradation.[34,35]

Microbes secrete enzymes that reduce the chain length of polymers and transport the oligomers, dimers and monomers into their cells for metabolic use.[23] Depolymerization occurs by enzymes which belong to hydrolases and oxidoreductases.[36] Cellulases, amylases and cutinases are hydrolases readily synthesized by soil microorganisms to hydrolyse natural abundant polymers such as cellulose, starch and cutin. Lipases hydrolyze the ester bonds of polyesters having a relatively large number of methylene groups, eg. poly(caprolactone) or PCL.

The metabolic processes involved in polymer depolymerization have been investigated in genome-based studies.[24] A common feature of hydrolases is a reaction mechanism that uses three amino acid residues: aspartate, histidine, and serine. The presence of these amino acids has been shown to be influential in the depolymerization of polyesters. Lipases, which are also depolymerases, have a common amino acid sequence incorporating glycine and serine.[34] Hydrolase enzymes capable of depolymerizing polyesters were shown to have exposed active site close to binding domains responsible for recognition and interaction with polymeric substrates.[37,38]

Biodegradation behaviour in various environments

There are many times when a product does not enter its intended disposal route and ends up outside of industrial or home composting environments. Biodegradation behaviour of BP is highly dependent on the surrounding environment. Humidity, temperature and microbe concentration vary in different environments and result in altered biodegradation rates, even for the same plastic type. PLA shows good break-down in managed environments (e.g. industrial compost, anaerobic digestion), but little degradation in unmanaged environments (soil, marine and fresh water) (Figure 6). PBS and PBAT are mechanically strong plastics and have been shown to only biodegrade in industrial compost environments. PHB and TPS plastics are two of the few biodegradable plastics shown to biodegrade in both managed and unmanaged environments (Figure 7). Some blends show improved biodegradation behaviour, yet others can be antagonistic in some environments leading to longer residence times in nature.

Anaerobic digestion is becoming a valuable end-of-life option, as many biodegradable plastics have high biochemical methane potential and contribute to the production of bio-gas that can be combusted into clean energy.[26] Many biodegradable plastic products have third-party certification for their ability to be composted, however, certification in anaerobic digestion conditions are less common.

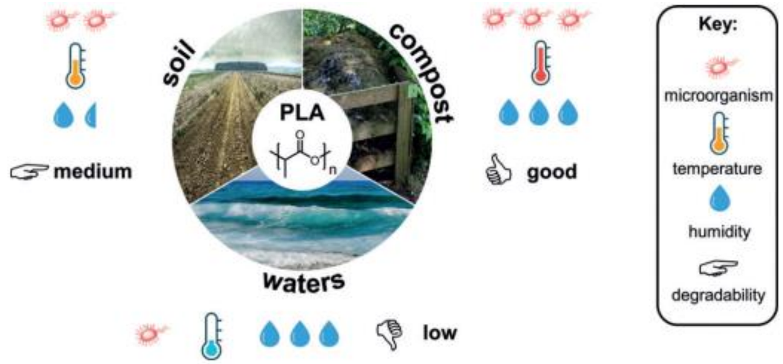

Figure 6. Influence of humidity, temperature and concentration of (suitable) microorganisms on the biodegradation of PLA in different environments.[25]

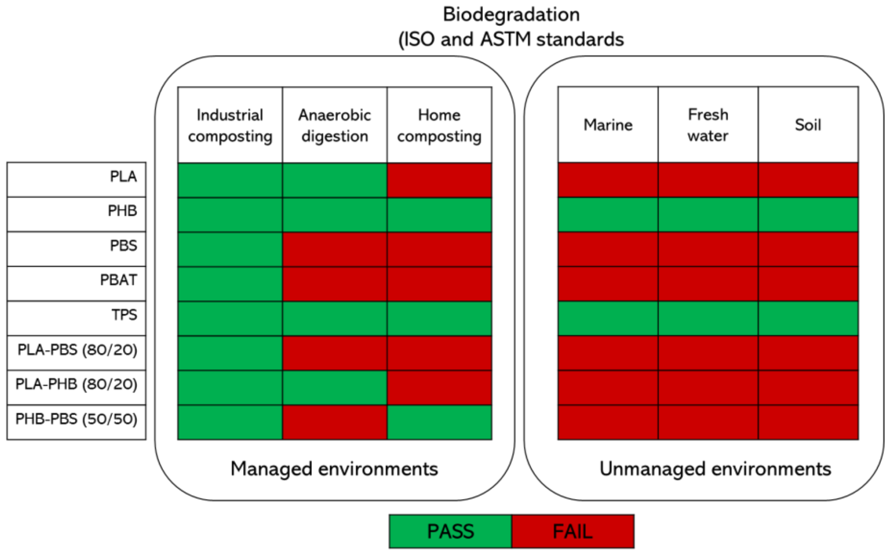

Figure 7. Biodegradation capacity of biodegradable plastics in managed and unmanaged environments tested according to international biodegradation standards.[26]

Impact of biodegradable plastics on compost quality and soil health

Biodegradable plastics are marketed as a method to reduce the environmental impact of plastic waste in the environment. Most of these products have been designed to degrade in compost processes, where the mature compost is intended to be applied to the soil as fertilizer. However, large scale field testing and long-term ecotoxicity data for biodegradable plastics is scare.

A recent study conducted in collaboration between Biodegradable Products Institute and the Foodservice Packaging Institute explored the effect of compostable foodservice items on the compost process. It was shown that foodservice packaging at 15% and 30% loading did not affect the balance of C:N ratios, nutrient levels, moisture content, or porosity to feedstocks or finished compost at the two facilities studied.[52] Other reports of field testing of compostable and biodegradable plastics focus on plastic disintegration and do not explore the effectiveness of the resulting soil or compost. Further exploration of this effect is imperative to the on-going use of these materials.

Ecotoxicity testing determines whether the material residuals, which are left behind after composting, show any inhibition on plant growth or the survival of soil fauna. Plant toxicity testing is a part of all norms on industrial compostability.[39] Timing of ecotoxicological assessments are important, as not only the main polymer but intermediate degradation products, plastics additives and fillers may become toxic during degradation.[40] Ecotoxicity testing has generally shown that commercially available BP products do not have adverse effects on soil biota, however these studies often focus on germination. There is less information on impacts on longer-term plant development.[41]

Work done on biodegradable plastic agricultural mulches have shown that BP may physically modify soil before it is fully biodegraded, this may be especially relevant under conditions that restrict soil microbial activity (i.e. low temperature or moisture levels). BPs may accumulate in soils reducing soil infiltration and water absorption before they are fully biodegraded.[42] Similar studies have also shown that changes in microbial community structures, stimulated microbial decomposition, and increased microbial biomass suggesting enhanced nutrient and carbon cycling under biodegradable plastic mulches, which may result in long term effects on soil organic matter dynamics. These initial studies have focussed on short term effects, or acute toxicity, so long term effects are currently unknown. The relationship between plastic composition and microbial responses needs exploration: different types of biodegradable plastics will likely differentially affect soil microbes, based on both the parent polymer composition and breakdown products.

Promoting biodegradable plastic degradation within commercial compost practises

Common commercial compost practises include turned windrow, aerated static pile and in-vessel composting.

Turned windrow composting is an open-air practise that places composting material into long piles called windrows. These windrows are turned regularly to ensure all the composting material spends time in the warm, moist centre of the pile where bacterial activity produces heat that encourages breakdown.[43] Windrow composting requires large amounts of land and a continual supply of labour to maintain the facility. Because windrow piles are situated outside, compost efficiency is dependent on weather conditions. In warm, dry climates, water evaporation can be a hinderance, and in colder climates, the pile might freeze reducing microbial activity.[44] Biodegradable plastics require very specific conditions in which to degrade and the variability in ambient atmosphere may cause inefficient BP degradation within windrow piles.[45] Ensuring extended residence times within the centre of the compost pile is important to be certain of complete BP degradation.

During aerated static pile composting, organic waste is mixed into a large pile. To ensure aeration, layers of loosely piled bulking agents are added so air can pass through the pile. Networks of pipes can also be placed beneath the pile to allow for controlled airflow based on temperature changes within the pile.[43] No physical turning is used with this method, so careful monitoring is required to ensure the all sections of the pile are heated. Being outside, static pile composting is also influenced by the climate at the compost facility.[44] Biodegradable plastics degrade through an interplay of abiotic and biotic action, and without turning or agitation, fragmentation of BPs may be slow, lengthening degradation times.[46] Size reduction prior to introduction into a static pile will ensure complete biodegradation.

In-vessel composting is a process that takes place within an enclosed environment. Organic materials are fed into a drum or silo which enables efficient control of environmental conditions such as temperature, moisture content and air flow. The material is mechanically turned or mixed to ensure the material is aerated, encouraging microbial activity. This method can produce compost in a shorter time-frame compared with other methods.[43,47] In-vessel compost reactors can be designed in a variety of sizes for different volumes of input materials. Also, because the incoming waste is well defined, and the atmosphere precisely controlled, this method can be optimized to process higher amounts of BP.

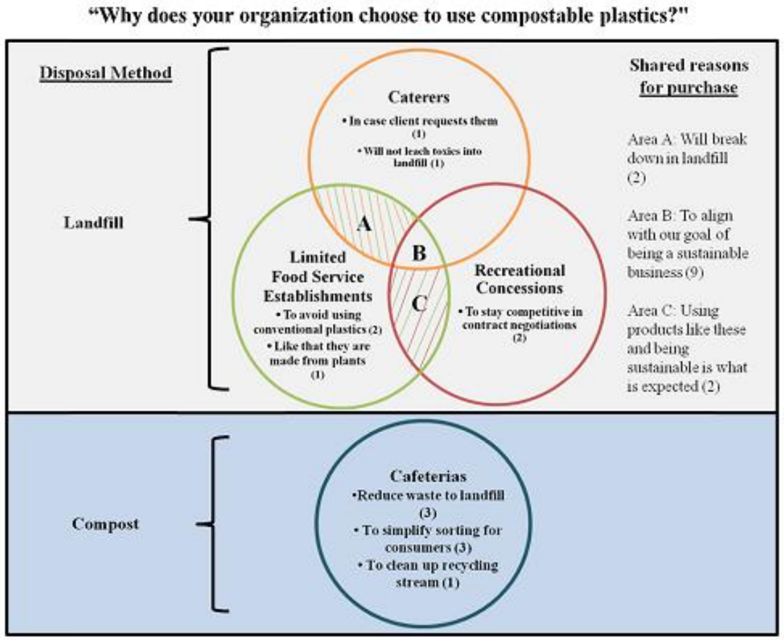

Figure 8. Responses given to the question "Why does your organization choose to use compostable plastics?" For each food service category there were three organizations interviewed; the four categories are Caterers, Limited Food Service Establishments, Recreational Concessions, and Cafeterias. The numbers in parentheses next to the stated reasons indicate how many organizations gave that particular response.[50]

Use of compostable products and packaging

Regional and municipal governments are beginning to implement policies targeting waste reduction and diversion of organic waste from landfills.[48] Several cities in North America have already adopted policies that make compostable or recyclable take-out food packaging compulsory.[49] Compostable foodservice products and packaging (CFP) refers both to complex biodegradable plastics that have third-party certification for compostability as well as plant fibre-based packaging that is commonly accepted to breakdown in compost facilities.

An case study in Arizona was conducted to understand where compostable plastics are commonly found, who is using them, and how organizations using these products are actually disposing of them.[50] An audit of packaging materials showed that the percentage of biodegradable plastics available at grocery stores is significantly lower than that of conventional plastics. Implying that consumers do not come into contact or purchase compostable products directly, and as such, disposal in residential settings is minimal. Consumers largely encounter CFPs in commercial food service settings, including caterers, recreational concessions, limited food service establishments and cafeterias. These organizations stated that the main drive to purchase compostable products was due to perceived environmental benefits which align with their corporate sustainability goals. However, survey of stakeholders uncovered that the majority of these commercial food service providers are sending their compostable products to landfills, with only cafeterias composting their materials due to ease in sorting. The major roadblock towards correct disposal was cited to be lack of access to commercial compost infrastructure able to accept their products (Figure 8).

Composter acceptance of foodservice packaging

A 2017 survey of North American compost operators showed that roughly half of composters accept compostable foodservice products, however this waste stream is generally less than 2 percent of total incoming material (Figure 9a). The most commonly accepted items were flexible BP bags, uncoated food-soiled paper and paper bags.[51] Very few composters are currently accepting rigid BP products such as cutlery. The majority of facilities accepting CFP operate windrows, while a quarter use aerated static piles; other popular technologies included in-vessel and mass bed systems (Figure 9b). To identify best practices that ensure more compostable foodservice items are successfully composted, Foodservice Packaging Institute sponsored a study in 2018, which was conducted by the Compost Manufacturing Alliance. The research found that extending active composting beyond typical operational timeframes and implementing pile management strategies to adjust moisture and temperature, allowed for increased CFP disintegration.[52]

Composters who may not be best suited to accept foodservice packaging include those that are manufacturing a "certified organic" product, as compostable plastics are currently not an allowable feedstock (this would also apply to paper items that have a compostable coating).

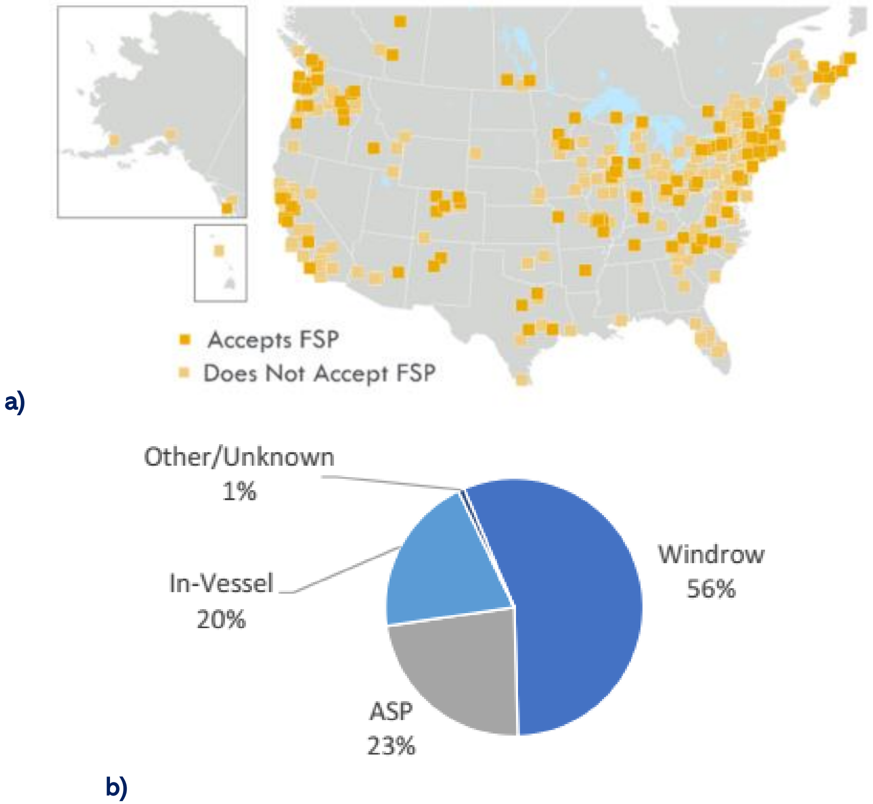

Figure 9. a) Map of North American compost facilities that accept and do not accept food service packaging (FSP). **b)** Technology used by composters that accept both food waste and foodservice packaging.

Conclusion

Due to performance requirements for use in various applications, a wide range of biodegradable plastics are now available on the market. This variability has led to some products showing slow biodegradation in current commercial compost operations. To overcome the insufficient biodegradation of some materials, most commercial compost operators only accept flexible compostable plastic bags and reject rigid plastic products such as compostable cutlery and cups. Minor alterations to the compost process are possible to ensure efficient and complete biodegradation, however, responsibility is placed on individual facility operators who are not incentivized to make these changes.

Biodegradable plastics breakdown through a synergy of abiotic and biological processes. These materials degrade via a process which begins with microbial adhesion and surface population followed by depolymerization and surface erosion and finally enzymatic hydrolysis and assimilation. Microorganisms use various mechanisms to degrade complex polymeric material including direct use of plastic fragments as a nutritional source or via the indirect action of microbial enzymes. The presence and abundance of microbial species able to degrade biodegradable plastic are highest in compost, followed by soil, fresh water, marine water and finally landfills. Those marketing biodegradable plastics must carefully analyse the degradation behaviour of their products in both managed and unmanaged environments order to avoid misleading claims.

Use and collection of biodegradable plastics into organic waste streams is increasing in some regions. Biodegradable plastics are generally considered to be non-toxic when degraded but knowledge gaps still exist in understanding the long-term effect of these materials on soil biota and plants. Some studies show that application of biodegradable plastic in soil may be beneficial while others give evidence of potential detrimental consequences. Each biodegradable plastic has different degradation products that will affect the environment in different ways. To support further development, field testing corroborated by laboratory tests should be used to assess the environmental and ecotoxicological impact of biodegradable plastic products.

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